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GRADY TRIPLETT
Editor

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VOLUME 19, No. 7 JULY, 1940

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AND NATURAL GASOLINE MANUFACTURER

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The Look Box

IN only raw material and technical knowledge is the petroleum industry ready to provide its share of national defense. It is lacking in plant capacity for the special products essential to 100-octane aviation gasoline. It must provide an intricate system of collecting these choice raw materials before plants can be operated at capacity.

Knowledge and Raw Material

Evidently it is enthusiasm which prompts the statements to the effect that the industry awaits only instructions of how much, where and when, whereupon ample supplies of choice aviation gasoline will be delivered in routine style. Before that can come about, some special plants must be built and an intricate system provided for bringing essential raw materials to these plants.

Thus far there is only speculation to indicate how much aviation gasoline defense will require. Frequently, the figure of 10,000 military airplanes is mentioned. With 6000 of these of the bombing type and 4000 of the pursuit type, and each active five hours each day, their gasoline consumption would be 5,000,000 barrels in a year. Should military activity be held at that level, no doubt another 5,000,000 gallons of aviation gasoline would go into training requirements in a year.

The industry has the raw materials for making this much aviation gasoline. In California* alone there are olefins from cracking stills and isoparaffins from natural gasoline for the making of 2,100,000 barrels of alkylate, from which 1,800,000 barrels of 100-octane aviation motor fuel could be provided by the addition of 1.5 ml lead per gallon. By blending this with suitable fractions of straight run gasoline and adding 3 ml lead per gallon, this alkylation product could be built into 2,900,000 barrels of what is now considered the choice aviation motor fuel.

California has less than a tenth of the cracking still capacity operated in 1939. The Texas Gulf Coast, with its 250,000 barrels of average output from cracking stills, offers sufficient gases for three times the California output. Nearby is the rich East Texas field for the paraffin side of manufacture. Cracking-still production of Oklahoma, Kansas and Missouri surpasses California, and the natural gasoline is nearby. The Chicago area and the Atlantic Coast offer additional cracking still capacity, but in these instances

* "Alkylation and Its Influence on Utilization of Natural Gasoline," Earl W. Gard, A. L. Blount and K. Korpi, Refiner, December, 1939, Page 63.

the required cut from natural gasoline is at a distance.

That the industry has the cracking still gases and the paraffins is evident. That it can build the plants for combining these raw materials is equally evident. Before these plants can be operated on a basis for 10,000,000 barrels of aviation gasoline each year, an intricate transportation system for bringing the paraffin to the olefin must be worked out.

The California estimate was based on a consideration of catalytic alkylation. The industry has thermal alkylation by which 115-octane gasoline can be provided. It has polymerization, gas reforming and hydrogenation, each a contributor to aviation gasoline, therefore, it does not seem extravagant to claim that the petroleum industry has the raw materials and the knowledge by which it can provide 20,000,000 barrels of 100-octane aviation gasoline in a year.

How long it would take to provide the plants and divert the raw materials to the plants are questions that halt any claims of providing unlimited amounts immediately. Like other industries, petroleum must be "tooled up" before it fulfills its job.

It must make additional investment, perhaps $100,000,000 for the equipment for putting together the olefins and paraffins, plus another healthy sum for bringing the paraffin to the plant.

Providing aviation-grade gasoline as well as other fuel is but part of the job for oil in military activity. The industry has synthetic rubber in production and knows other methods of converting oil into a substitute for the plant base for tires. It is but a step from present refining of crude oil to the making of explosives, for the worst of the knocking hydrocarbons are a raw material out of which TNT can be made.

Thus the job for oil enlarges in keeping with the restriction on imports into the United States. Magnitude of the job is beyond calculation of cost or time of actual delivery of all these materials. The industry simply has the raw materials and knows how to convert them.

Immediately, the task for oil seems to be ample aviation-grade motor fuel. Rubber and explosives will come from oil if and when natural sources are not available.

Doubtless the industry prefers to provide its products under private ownership and free enterprise. If its funds go into new plants for a special purpose, the profit motive seems just. This is the attitude of government, which gives the industry opportunity to perform as well as it did in World War I. By so doing it can justify profit and free enterprise for the public and to itself.

The industry is fortunate to draw Dr. Robert E. Wilson as its representative on the Industrial Advisory Commission of the Council of National Defense. He knows what the industry has and what it can do. If he can advise what the government needs, it can be provided as time and investment permit.

The attitude of the oil industry is the attitude of American citizens. Its desire for profit and free enterprise is based on the conviction that these will best serve national defense and in time best serve American citizens. Despite the necessity of national defense, men cling to the hope that war is not the way of life. If this is in prospect, a time will come when men will return to building rather than destroying, and the petroleum industry desires to be a part of that period as well as the present.

Profit to an industry, a corporation or an individual is of no consequence in defense of a nation. Only when profit allows adequate contribution to defense and permits it to emerge in better condition for peace can the profit motive be justified. It is on this basis that the industry is ready to take its part in the program.

As the industry takes up its share of this program, it asks nothing for itself. It has the raw material, the knowledge and the personnel to provide what defense demands in fuel. If it can fulfill this obligation under the stimulus of free enterprise, it will all the better be able to play a vital role in whatever form of civilization comes out of a crisis whose consequences defy calculation.

Good Policy Evident

COMPLIMENTS are in order for the Central States Petroleum Union, whose letter to the President June 12 gave this assurance:

"Be it declared that the Central States Petroleum Union locals and members in the oil industry do now declare for the period of the present rearming program they will not strike or walk out or in any way disrupt the output of manufactured products vital to our national defense.

"All questions and problems between the employer and the union which we are unable to settle will be submitted to the conciliation service of the Department of Labor for settlement."

The attitude represents determination to get things done. It would be admirable for the concerns in which these men work to make similar declarations. Of importance equal to the attitude is the prospect that there will be no need for submitting differences to the Department of Labor. Workmen who are determined not to disrupt plant output rarely find capital willing to decline equitable settlement.

The Rolling-in of Upset and Close Tolerance Machined Tools for Cracking Furnace Installations

By F. C. BRAUN, Engineer of Gulf Oil Corporation and
MARTIN FLEISCHMANN, Metallurgical Engineer,
Timken Roller Bearing Company

THE rolling-in of tubes into headers presents problems which have never been thoroughly investigated. These problems are of especial importance to the oil industry where the advance of the oil refining technology demands the use of higher and higher temperatures and pressures. At these operating conditions the importance of tight and strong rolled joints between cracking furnace tubes and headers may readily be visualized as a failure of these connections not only may jeopardize large capital investments but also endanger human lives.

The common practice of rolling in tubes just as they come from the mill with the adherent scale and surface imperfections, irregular wall thicknesses and more or less eccentric shapes, has no doubt been largely responsible for many of the joint failures.

It appeared logical to assume that upsetting of the tube ends, followed by machining the inside and outside to close tolerances previous to the rolling-in operation, may eliminate many irregularities and offer a possible solution to the problem on hand.

In order to gain information in regard to certain variables in the rolling-in technique which may affect the tightness and safety of these rolled joints, an investigation was conducted by Gulf Oil Corporation in cooperation with Key Company and Timken Steel & Tube Division of Timken Roller Bearing Company.

Material Used in Investigation

The tubing material was furnished by Timken in the annealed condition, comprising 6 standard types of pearlitic steels used by the oil industry in cracking-furnace tubes. The sample tubes were 2 feet long, with one end upset, inside and outside, and machined to close tolerance, according to the dimensions specified by Gulf Oil Corporation. Two different sizes of outside diameters were used, 5- and 4¼-inch, and wall thicknesses of ⅝-, ½- and ⅜-inch were chosen. These dimensions are typical for cracking-furnace tubes. The tube samples, their dimensions and their compositions are listed in Table 1. All alloy tubes had been annealed to a maximum hardness of 163 Brinell.

The headers used were in the form of heavy wall sleeves. They were produced from steel castings of plain carbon as well as 5 percent Cr-Mo composition, designated K-1 and K-4 respectively. The carbon steel headers, K-1, conformed to a hardness range of 131 to 146 Brinell, while the 5 percent Cr-Mo sleeves (K-4) were heat treated to a hardness range of 192 to 255 Brinell. The inside diameter of the sleeves was machined to close tolerance, containing a tube stop as well as definite serrations into which the tube material had to be expanded. The machining tolerances allowed about .004-inch to .008-inch clearance between the upset and machined O.D. of the tube and the closely machined tube hole of the header.

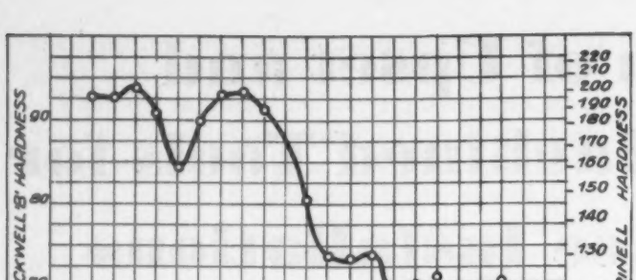
Rolling-In Procedure

Standard tube expanders were used in expanding the upset ends of the tubes into the headers. The dimensions of each machined tube end as well as the dimensions of the machined tube hole of each corresponding header were checked accurately previous to the rolling-in operation. The amount of expansion of the tube into the header was varied not only on tubes of different steel types but also within samples of the same group. The effect of changes made in the rollers and set up of expander tool were also investigated and noted.

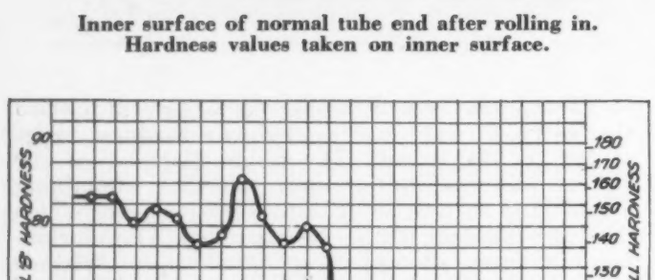
The elongation of the tube out of the header, ob-

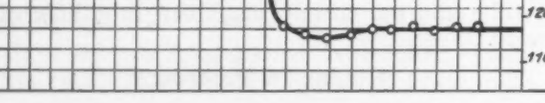
TABLE 1

Code	No. Pcs.	Type	SIZE O.D.	SIZE Wall	ANALYSIS C	Mn	P	S	Si	Cr	Mo
P- 1	4	Carbon	5″	x⅝″	.12	.48	.016	.032	.15	....	....
P- 2	4	Carbon	5″	x½″	.12	.41	.014	.023	.14	....	....
P- 3	4	Carbon	5″	x⅜″	.13	.43	.017	.027	.15	....	....
P- 4	4	Catbon-Mo	5″	x⅝″	.13	.44	.020	.016	.24	....	.53
P- 5	4	Carbon-Mo	5″	x½″	.14	.49	.013	.020	.24	....	.50
P- 6	4	Carbon-Mo	5″	x⅜″	.15	.43	.018	.023	.19	....	.55
P- 7	4	2% Cr-Mo	5″	x⅝″	.12	.44	.008	.013	.30	2.05	.55
P- 8	4	2% Cr-Mo	5″	x½″	.10	.40	.014	.016	.31	1.98	.59
P- 9	4	2% Cr-Mo	5″	x⅜″	.11	.40	.012	.012	.30	2.05	.55
P-10	4	4/6% Cr-Mo	5″	x⅝″	.12	.44	.015	.017	.33	5.33	.57
P-11	4	4/6% Cr-Mo	5″	x½″	.13	.40	.016	.015	.33	5.28	.56
P-12	4	4/6% Cr-Mo	5″	x⅜″	.13	.40	.016	.015	.33	5.28	.56
P-13	4	6/8% Cr-Mo	5″	x⅝″	.11	.40	.013	.016	.36	7.14	.55
P-14	4	6/8% Cr-Mo	5″	x½″	.11	.40	.013	.016	.36	7.14	.55
P-15	4	6/8% Cr-Mo	5″	x⅜″	.11	.40	.013	.016	.36	7.14	.55
P-16	4	8/10% Cr-Mo	5″	x⅝″	.08	.44	.009	.012	.35	8.85	1.10
P-17	4	8/10% Cr-Mo	5″	x½″	.08	.44	.009	.012	.35	8.85	1.10
P-18	4	8/10% Cr-Mo	5″	x⅜″	.08	.44	.009	.012	.35	8.85	1.10
P-19	2	Carbon	4¼″	x⅝″	.16	.52	.011	.022	.25	....	....
P-20	2	Carbon	4¼″	x½″	.13	.48	.014	.030	.15	....	....
P-21	2	Carbon	4¼″	x⅜″	.13	.42	.015	.033	.15	....	....
P-22	2	2% Cr-Mo	4¼″	x½″	.12	.43	.015	.012	.33	2.06	.56
P-23	2	4/6% Cr-Mo	4¼″	x½″	.13	.41	.011	.015	.35	5.17	.56



Inner surface of normal tube end after rolling in. Hardness values taken on inner surface.





Etch test and hardness values taken on radial section

FIGURE 1

served during the rolling-in operation, was recorded by means of a strain gauge suitably attached to the assembly.

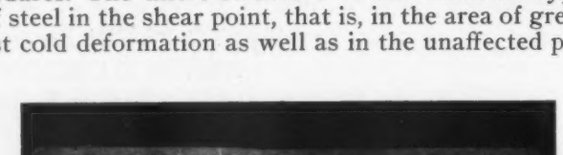
After the tube was rolled into the header, the sleeve was removed again by making two longitudinal cuts on opposite sides through the header. The O.D. and I.D. dimensions of the tube-end after rolling were now obtained. Approximately four inches of the upset end of the tube were sawed off and one longitudinal cut made through this portion of the tube. The internal stresses set up in the material during the rolling-in operation are indicated by the spring out of the ring after the longitudinal split. In fact the amount of spring measured after "miking" the O.D. of a rolled-in tube section before and after splitting is in direct relation to the magnitude of the stresses present and is a function of the amount of rolling.

As these stresses act in a radial and tangential direction, they tend to press the material against the I.D. of the tube hole in the header, contributing to the tightness of the joint.

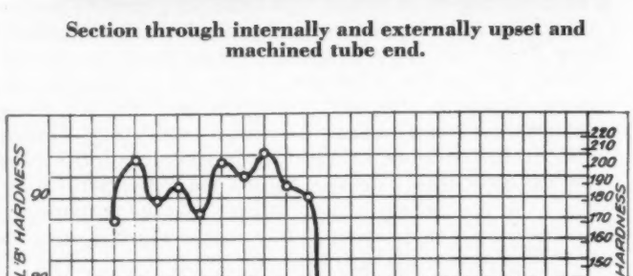
Metallurgical Tests

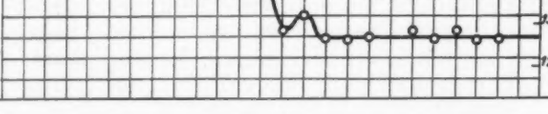
A segment from each tube end after the rolling-in operation was submitted to the Metallurgical Department of Timken Roller Bearing Company for investigation.

Longitudinal strips were machined from these sections, ground parallel on the cut surfaces and used for the hardness survey. The Rockwell Hardness Tester was employed to determine the hardness of the samples. The same sample after regrinding was also etched in 50 percent hydrochloric acid to reveal the grain flow in the material. Macrographs of these specimens illustrate the variations in the quality of the shear points obtained by various rolling-in procedures. The micro-structure of the different types of steel in the shear point, that is, in the area of greatest cold deformation as well as in the unaffected por-

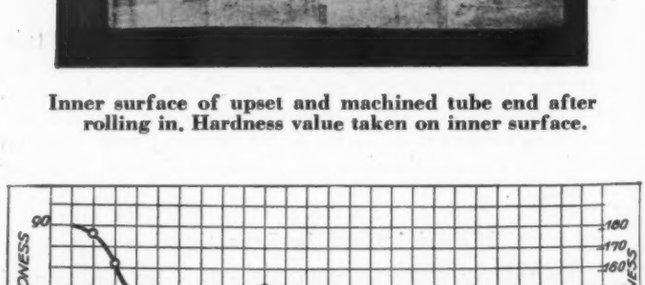


Section through internally and externally upset and machined tube end.





Inner surface of upset and machined tube end after rolling in. Hardness value taken on inner surface.



Etch test and hardness values taken on radial section.

FIGURE 2

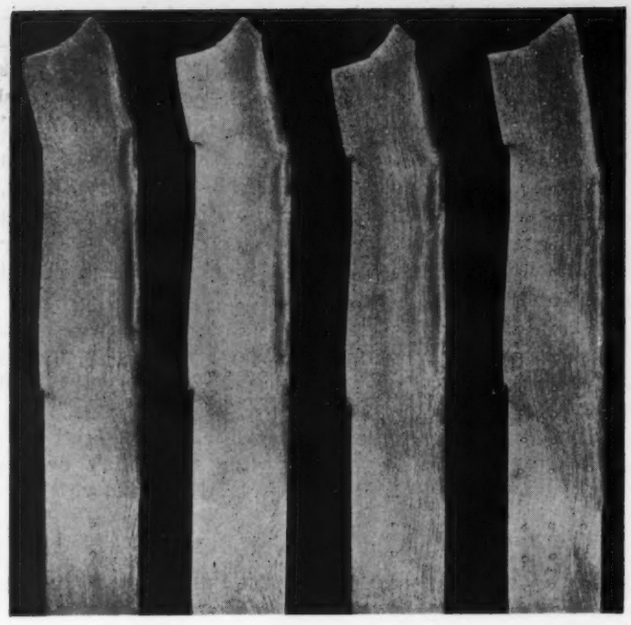


FIGURE 3

Macrographs of expanded portions of C-Mo steel tubes, 5-inch O.D. x ⅝-inch wall.

TUBE No.	1	2	3	4
Brinell Hardness	134	126	137	131
O.D. at Upset	5.063″	5.063″	5.063″	5.062″
I.D. at Upset	3.545″	3.545″	3.548″	3.544″
Expansion of Tube End	12/64″	13/64″	14/64″	8/64″+4/64″
O.D. after Rolling	5.072″	5.076″	5.075″	5.078″
O.D. after Longitudinal Splitting	5.087″	5.090″	5.088″	5.086″
Difference =Spring Out	.015″	.014″	.013″	.008″
Elongation during Rolling	.110″	.125″	.165″	.025″+.115″
Header Material	K-4	K-4	K-4	K-4
Brinell Hardness	217	202	235	212
I.D. of Tube Hole	5.069″	5.068″	5.068″	5.068″
Depth of Serration	.061″	.063″	.061″	.061″
Expander Size	3.625″	3.625″	3.625″	3.625″

REMARKS—No. 4 Test: Rolled without flaring rolls for 8/64″ expansion, rolled additional 4/64″ with special flaring rolls 5½° incl. angle.

tion of the tube was recorded in photomicrographs at 100 and 1000 magnifications.

A comparison between the quality of rolled joints obtained with plain hot-rolled tube ends against upset and closely machined tube ends may be made from Figure 1 and Figure 2. Figure 1 shows the the appearance of the inside surface and a radial section through the wall of a conventionally rolled tube end. The graphs above the sections indicate the changes in hardness as a result of the rolling-in operation. It is to be observed that the inside surface is severely cold worked, which frequently causes flaking, and that considerable thinning of this section has occurred. This is especially objectionable since the most severe corrosion usually occurs on the tube ends. The importance of having sufficient strength in the headers to support the rolling pressures and to balance the strengthening of the tube wall during the cold-working operation is evident.

Figure 2 shows a section through an internally and externally upset tube end machined to close tolerances and likewise the appearance of the inner surface and radial section after the rolling-in operation. As before similar hardness values are included. Unlike the previous condition the inner surface has remained smooth and free from all defects and the radial section indicates that the wall thickness has been well maintained.

From the large accumulation of data obtained during the rolling tests on upset and close machined tube ends of various types of steel, a few typical examples may suffice to illustrate the effect of different variables.

Figure 3 illustrates four sections through the rolled in portion of carbon-molybdenum steel tubes 5-inch O.D. x ⅝-inch wall. The Brinell hardness of each tube end as well as O.D. and I.D. dimensions at the upset, previous to the rolling-in operation, are given. Each tube was expanded into a cast and heat treated 5 percent Cr-Mo sleeve of given hardness and I.D. dimensions. The amount of expansion is noted, also the O.D. dimension of the tube end after rolling-in and after longitudinal splitting. The difference between the two O.D. values constitutes a measure of internal stresses introduced by the rolling-in operation. The elongation of the tube out of the header, observed during rolling, also was recorded.

It may be observed that an expansion of 12/64-inch was not sufficient to produce two well developed shear points on this size of tubing. While excellent

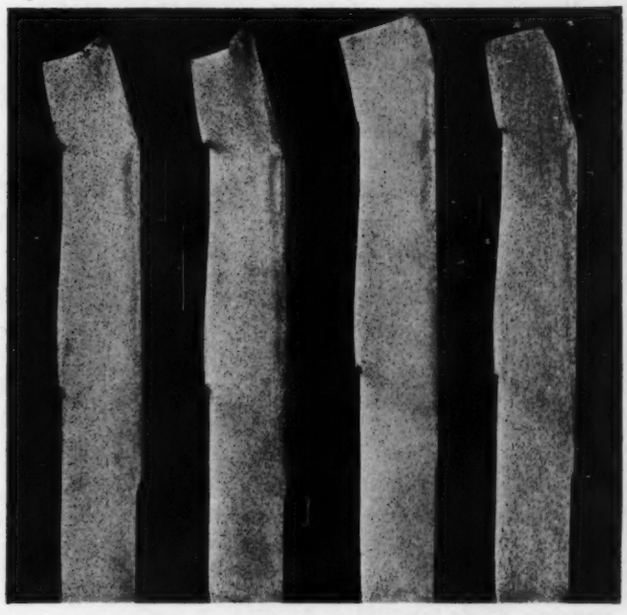


FIGURE 4

Macrograph of expanded portion of C-Mo steel tubes, 5-inch O.D. x ½-inch wall.

TUBE No.	1	2	3	4
Brinell Hardness	140	140	137	140
O.D. at Upset	5.064″	5.063″	5.060″	5.062″
I.D. at Upset	3.826″	3.824″	3.826″	3.826″
Expansion of Tube End	8/64″	10/64″	10/64″	10/64″
O.D. after Rolling	5.074″	5.073″	5.075″	5.074″
O.D. after Longitudinal Splitting	5.092″	5.087″	5.089″	5.090″
Difference =Spring Out	.018″	.014″	.014″	.016″
Elongation during Rolling	.150″	.160″	.080″	.130″
Header Material	K-4	K-4	K-4	K-4
Brinell Hardness	217	255	233	202
I.D. of Tube Hole	5.068″	5.070″	5.069″	5.068″
Depth of Serration	.060″	.059″	.061″	.059″
Expander Size	3.875″	3.875″	3.875″	3.875″

REMARKS—No. 2 Test: Stop on Expander Moved Back 1½ Rev.
No. 3 Test: Flaring Rolls Removed.

FIGURE 5

Macrograph of expanded portions of C-Mo steel tubes, 5-inch O.D. x 3/8-inch wall.

TUBE No.	1	2	3	4
Brinell Hardness	131	116	118	121
O.D. at Upset	5.063"	5.063"	5.063"	5.063"
I.D. at Upset	4.109"	4.110"	4.109"	4.108"
Expansion of Tube End	8/64"	7/64"	7/64"	7/64"
O.D. after Rolling	5.075"	5.073"	5.074"	5.074"
O.D. after Longitudinal Splitting	5.085"	5.087"	5.090"	5.100"
Difference = Spring Out	.010"	.014"	.016"	.026"
Elongation during Rolling	.160"	.095"	.146"	.120"
Header Material	K-4	K-4	K-4	K-4
Brinell Hardness	217	229	197	197
I.D. of Tube Hole	5.069"	5.069"	5.069"	5.069"
Depth of Serration	.059"	.059"	.061"	.061"
Expander Size	4.1875"	4.1875"	4.1875"	4.1875"

REMARKS—No. 2 Test: Flaring Rolls Removed.
No. 3 and No. 4 Test: Special Flaring Rolls 5½° Included Angle.

shear points were obtained with the given rolling tool and an expansion of 14/64-inch, the appearance of the joint could be further improved by the use of smaller angle flaring rolls, giving an additional expansion of 4/64-inch, subsequent to a straight expansion of only 8/64-inch. This latter set up also produced the minimum amount of longitudinal metal flow.

Similar conditions are indicated in Figure 4, working with 5-inch O.D. x ½-inch wall tubes and expansions of 8/64- and 10/64-inch respectively.

Our experiments with carbon-molybdenum steel tubes 5-inch O.D. x 3/8-inch wall, a relatively thin-walled tube, are shown in Figure 5. The best rolling job was obtained with only 7/64-inch expansion of this tube using special flaring rolls of only 5½° included angle.

The hardness distribution in the tube ends after rolling was checked for each type of steel and for each tube size. A typical example is shown graphically in Figure 6, illustrating the hardness survey of the rolled-in portions of 7 percent chromium-molybdenum tubes, 5-inch O.D. with three different wall thicknesses.

The original tubes had been annealed to a maximum hardness of 163 Brinell. An increase in hardness of approximately 20 Rockwell "B" units, corresponding to about 80 Brinell numbers, was the result of the cold working of the tube material during the rolling-in process. The areas, where hardness values in excess of Rockwell B 90 were determined, have been shaded in the drawing Figure 6, and fields of similar hardness have been lined out, giving a clear picture of the hardness distribution of the rolled tube ends.

The deformation of the grain structure at the location of the shear points is illustrated in the photomicrographs Figure 7 and Figure 8 at 100 and 1000 magnification.

It is generally assumed that the preferential corrosion attack on the ends of the tube may be associated with the deformed crystal structure.

Conclusion

From a study of the extensive data secured in this manner the following conclusions may be drawn:

1. The header material should be considerably harder than the tubing to assure well developed shear points. It is suggested that headers for the installation of alloy tubes with a maximum hardness of 163 Brinell should be heat treated to a hardness of 220 Brinell minimum. In general it is recommended that the hardness of the header should ex-

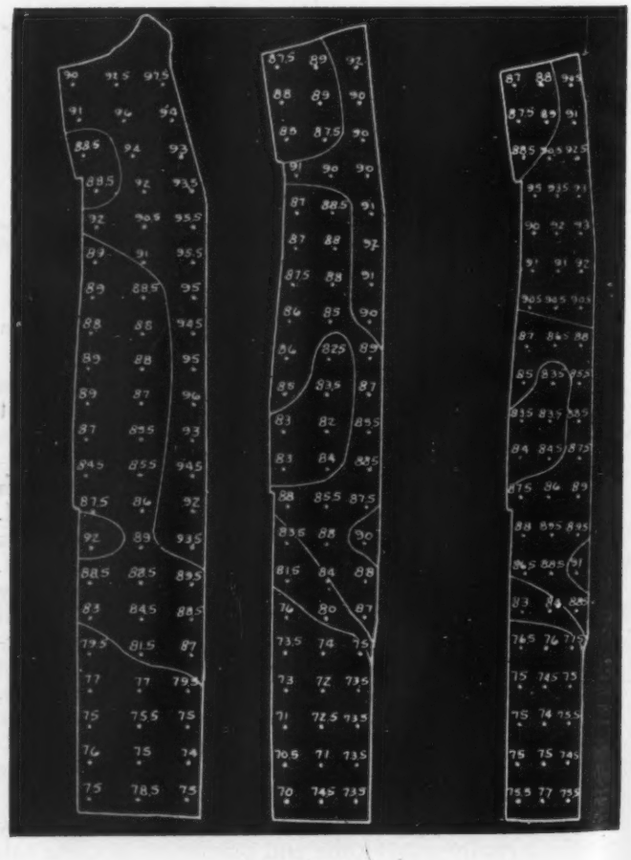


FIGURE 6

Hardness survey of expanded tube ends—5-inch O.D. tubes 7 percent chromium-molybdenum steel. Indicated numbers represent Rockwell B hardness values.

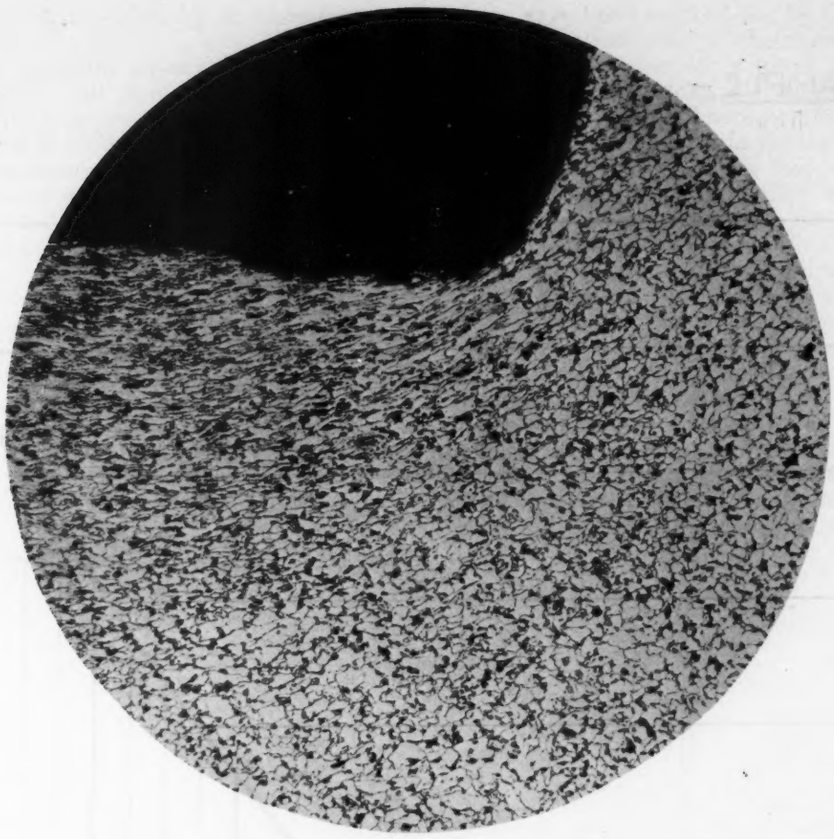


FIGURE 7

Structure of carbon-moly tube at shear point, 100X

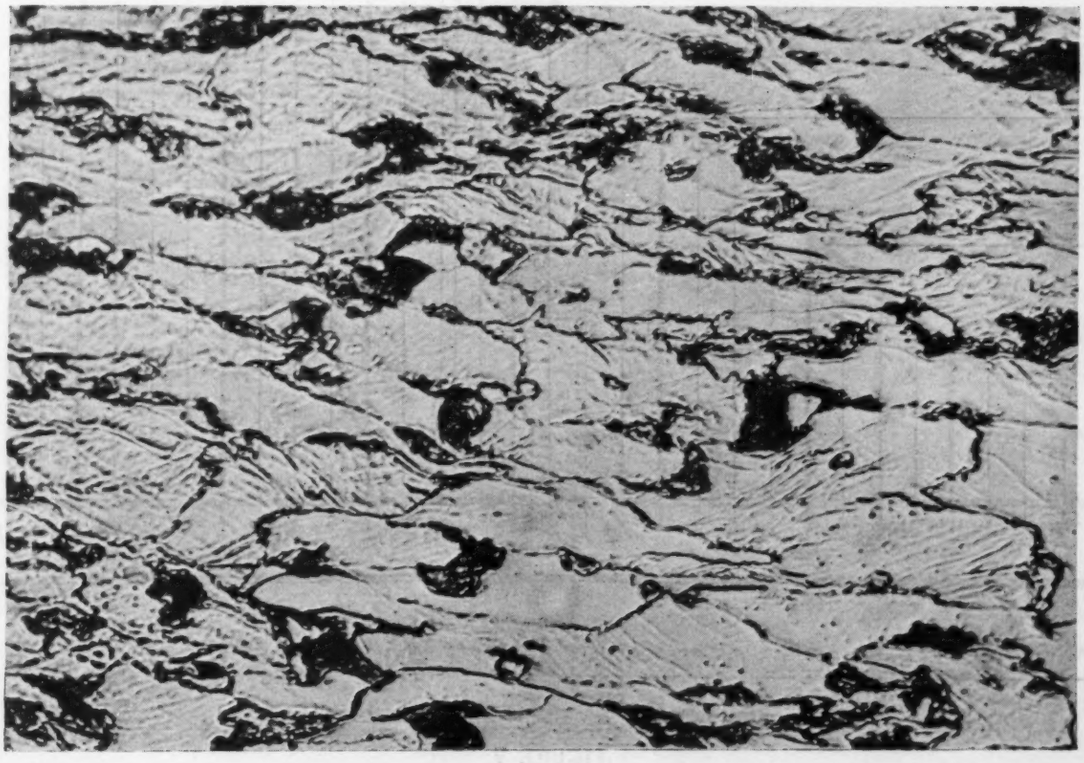


FIGURE 8

Structure of carbon-moly tube at shear point, 1000X

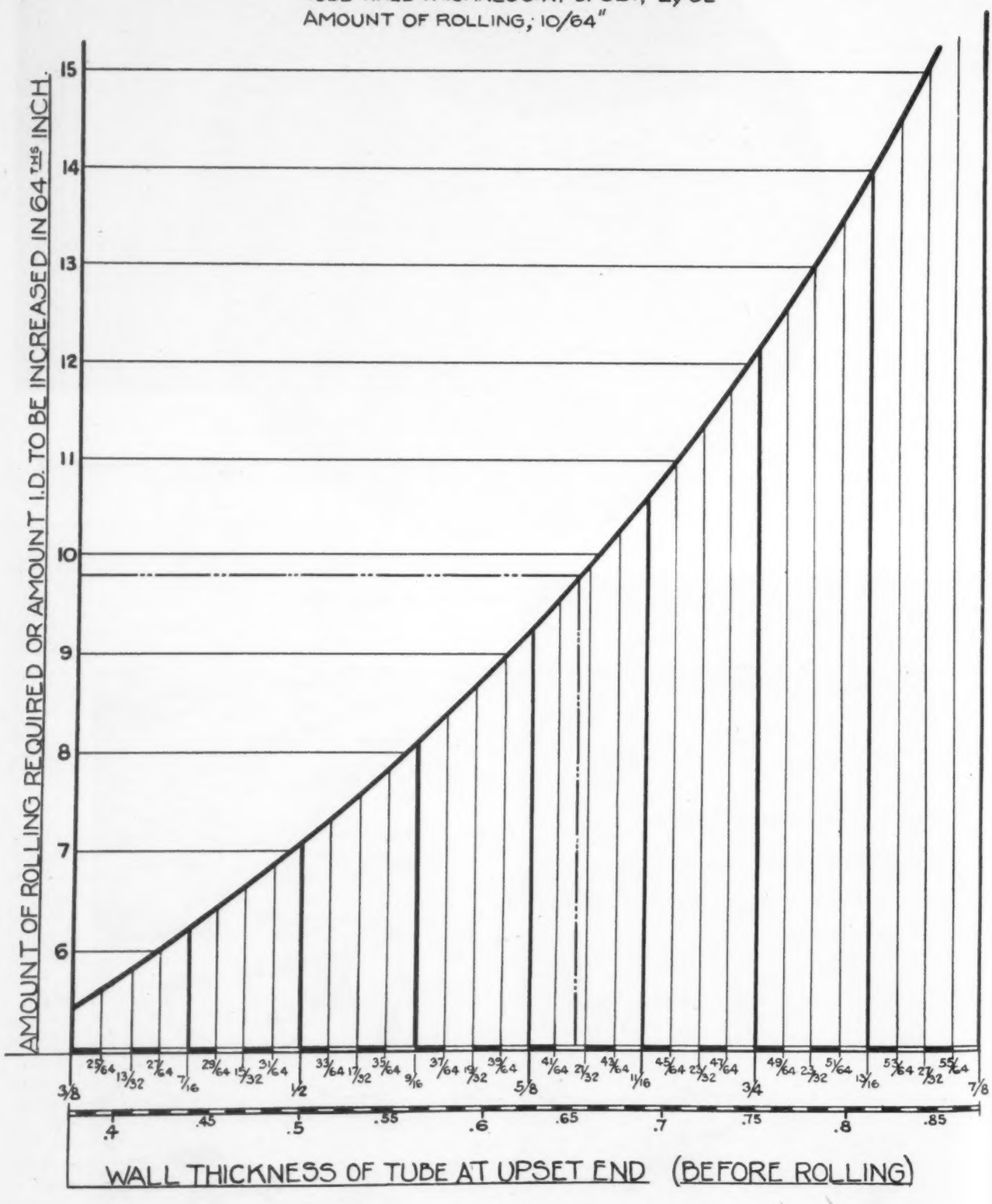


FIGURE 9

Chart indicating the recommended expansion for a given size tube end, upset and machined to close tolerances.

ceed the hardness of the tubes by a minimum of 60 Brinell numbers.

2. There is an optimum amount of expansion for each tube size which will produce best shear points and tightest fit. Not only insufficient rolling, but also too much rolling will cause joints of doubtful quality. Too much expansion of the tube into the tube hole will result in an excessive flow of the tube material out of the header with the danger of shearing off proper shear points which already have been formed.

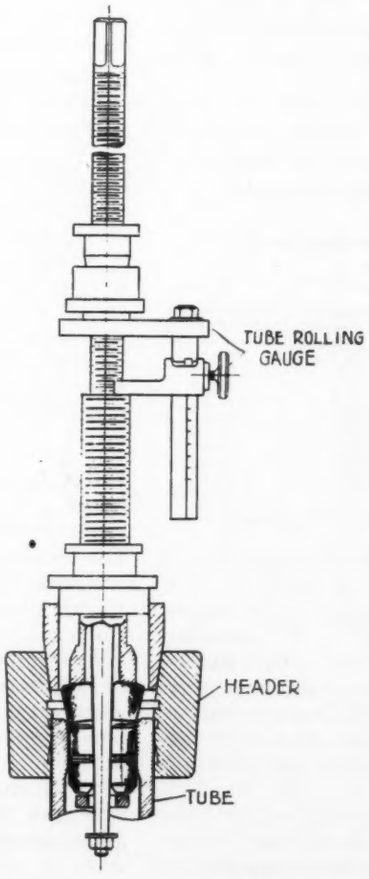
3. The use of wide angle flaring rolls on the expander tool should be discouraged as the flaring of the tube ends will cause a longitudinal flow of the tube material, injuring satisfactory shear points formed by the expander rolls.

The conclusions reached give tangible support to the belief that it is sound engineering practice to upset and machine to close tolerances tubes which are rolled into headers, keeping in mind the precautions outlined.

Based upon this investigation, definite specifications have been worked out by Gulf Oil Corporation. Figure 9 illustrates a chart indicating the recommended expansion for a given size tube end, upset and machined to close tolerances.

A new "rolling-in" tool has been developed, incorporating narrower angle flaring rolls, as suggested by the investigation. This tool also is designed with definite settings corresponding to the predetermined, recommended expansions in sixty-fourths. This new tool, illustrated in Figure 10, should take much of the guess work out of the rolling-in of tubes.

The adoption of upset and close machined tube ends in cracking furnaces will provide an important safeguard for capital investment and human lives. In addition to this safety feature, it is felt that the reductions in the amount of cold rolling possible with upset and close machined tubes will bring with it a definite decrease in end corrosion, prolonging the actual service life of the tubes. The use of upset and close machined tube ends, therefore, not only provides safer operation but also will prove more economical.



COMBINATION ROLLING & FLARING TOOL

FIGURE 10

Newly developed rolling-in tool

Welding Requirements of Carbon-Molybdenum Pressure Piping

By WELDON L. ARCHER

To satisfy design requirements calling for ever increasing temperatures and pressures progressive refinery operators have turned to the use of carbon-molybdenum piping. The ubiquitousness of this material is seen in its application to high-temperature and pressure service in connection with oil stills, cracking units, pumps, valves, pressure vessels, boilers and piping. This discussion will be confined to the high-temperature piping aspect of the problem.

In order to meet the demands of pressure-piping service a material must possess certain physical attributes among which are adequate strength at elevated temperature; good resistance to oxidation and scaling as well as corrosion resistance; excellent ductility and toughness in service; proper weldability; and satisfactory fabrication characteristics. Fortunately carbon-molybdenum steels fulfill these conditions quite well.

Considering, first, strength at elevated temperatures as disclosed in Table 1 it is readily seen that small carbon steel containing just over 0.5 percent of

TABLE 1

Quick Tensile Strength of Carbon-Molybdenum Steel at Various Temperatures

Testing Temperature ° Fahrenheit	Tensile Strength psi	Elongation 2"—Percent	Reduction of Area—Percent
70	71,800	34.3	66.8
800	71,125	27.8	70.6
900	63,500	27.5	75 8
1000	57,500	29.0	76 6
1100	45,100	38.0	83.9
1200	27,000	60.0	88.3
1300	16,180	82.5	93.9
1400	8,720	94.0	85.8
1500	8,650	76.0	55.1
1600	8,470	65.0	49.3

molybdenum suffers a relatively small dimunition of strength at temperatures as high as 1100° F. The material reported in Table 1 conforms to the following basic analysis which is typical for the low-alloy steel reported in this article: carbon, 0.10-0.20 percent; maganese, 0.30-0.60 percent; silicon, max., 0.25 percent; phosphorus, max., 0.04 percent; sulfur, max., 4.045 percent; and molybdenum, 0.45-0.65 percent. But high temperature tensile strength does not tell the whole story.

Resistance to oxidation and to attack from corroding media is not a strong point in the use of low-alloy steels. For this reason there may be installation conditions that will prohibit the use of carbon molybdenum pressure piping. Sometimes sacrificing metal thickness to corrosion proves to be the most economical approach to the problem. Should the corrosion situation be too severe for this solution, a higher alloy is indicated.

Next in order is attention to ductility and toughness during the period of service. In Table 1 it was noted that ductility as measured by the elongation

TABLE 2

Impact Strength of Carbon-Molybdenum Steel at Various Temperatures

Testing Temperature ° Fahrenheit	Charpy Impact in Ft.-Lbs.	
	1 Hour at Temp.	1,000 Hour at Temperature
85	32.7	.....
500	44.7	44.3
600	41.0	46.5
750	38.7	35.0
900	26.3	26.7
1000	25.5	30.0
1100	31.0	38.0
1200	56.0	27.3

in two inches and the reduction of area in percent increased until a temperature over 1300° F. was reached. Since pressure piping as considered here does not operate over 1100° F., the ductility was considered as quite good. Similarity with the impact strengths reported in Table 2 the values to 1100° F. are approximately equal to or better than the figures reported for room temperature. So on the score of toughness as customarily measured by impact tests this low alloy receives a passing grade. Not only is the impact strength sufficient at the elevated temperatures reported but also is the strength adequate after holding for 1000 hours at the indicated temperature.

Favorable Welding Qualities

No doubt the ease with which the molybdenum-bearing materials may be welded has contributed much to their widespread adoption. Since there are a few commonly accepted rules to be followed in the welding operations, a detailed discussion will be undertaken later. Suffice it to say for the present that no fears may be anticipated regarding the weldability of this particular analysis.

Suitability for rolling, forging and piercing is important to the refiner as it affects the final price of the completed piping. Here, too, molybdenum allows the steel to be fabricated with an ease approaching that of mild steel, bearing in mind, of course, the strength difference that exists. Where the refiner is purchasing fabricated piping, he may not appreciate ease of fabrication as reflected in prices as much as he would if he were performing the work himself.

All of the points enumerated have an important bearing on the selection of carbon-molybdenum piping for high-pressure and high-temperature service. Still to be considered is the question of creep strength. For creep behaves far differently from

other physical properties as measured at elevated temperatures. Into the question of creep strength enters another factor: time.

Under the influence of relatively low stresses at elevated temperatures steels grow. This growth, yielding or extension under the combined influences of temperature, stress and time, known as creep, has been evaluated by tests and reported as creep strength. Creep strength data may be reported as the stress which causes an elongation of 1 percent in 100,000 hours or that stress which causes an elongation of 0.1 percent in 10,000 hours at the temperature under consideration. In this manner the rate of elongation has been used to establish design

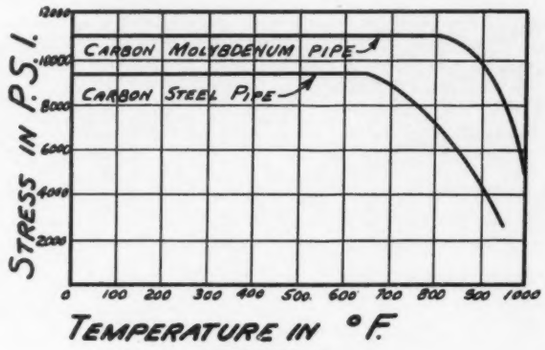


FIGURE 1
Allowable Stresses in P. S. I.

data. And in Figure 1 are compared the allowable stresses for low-carbon seamless-steel piping conforming to ASME S-18 and carbon-molybdenum piping conforming to ASME S-45. From this figure the advantage in using the alloyed piping is readily observed.

So much for the design considerations and reasons for the selection of this material for pressure piping at elevated temperatures. Now what about the welding procedure? Since the work will most likely be conducted under the American Tentative Standard Code for Pressure Piping (ASA B-31) or the ASME Power Boiler Code which is almost identical, the first step requires the qualification of the welding process and the welding operators.

Although there is really nothing complicated about the qualification rules, this point has proven a stumbling block to the uninitiate. For that reason it is well to go through a detailed welding procedure for the welding of carbon-molybdenum pressure piping.

The process shall be either the metallic arc process or the oxy-acetylene process. Here the fabricator is given his choice. His decision may be based upon the experience of the operators in his employ or his preference for one process rather than the other.

Next the type of base metal must be described. In this case the base material is that conforming to ASME S-45. Further, the filler metal must be mentioned. Here the manufacturer's name or grade and the American Welding Society specification must be given. The welding-wire manufacturer can furnish this information. Usually he can furnish valuable assistance in drawing up the welding procedure as well.

The preparation of the base metal must be described. The edges or surfaces of the parts to be joined by welding shall be prepared by machining, grinding or flame treatment. The choice is left to the fabricator and he selects his regular method. A detail of the welding groove is included as shown in Figure 2. The surfaces of the parts to be welded must be cleaned of all oil or grease and excessive amounts of scale and rust.

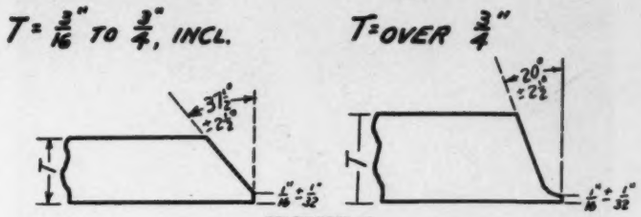


FIGURE 2
Welding Groove Details

Then the method of welding is explained. In the case of arc welding the current characteristics and electrode size together with operating manipulation must be detailed. For oxy-acetylene welding the corresponding information about that process should be described.

Each bead must be carefully cleaned before depositing the next pass of welding. Any cracks or blow- holes that appear on the surface of any bead of welding must be removed by chipping or flame deseaming. This detail must be listed.

What about peening? A moderate peening is required for piping under ¼-inch thick, while piping over that wall thickness should be peened stoutly. Peening avoids the formation of cracks from weld shrinkage.

Preheating to temperatures from 300° F. to 500°

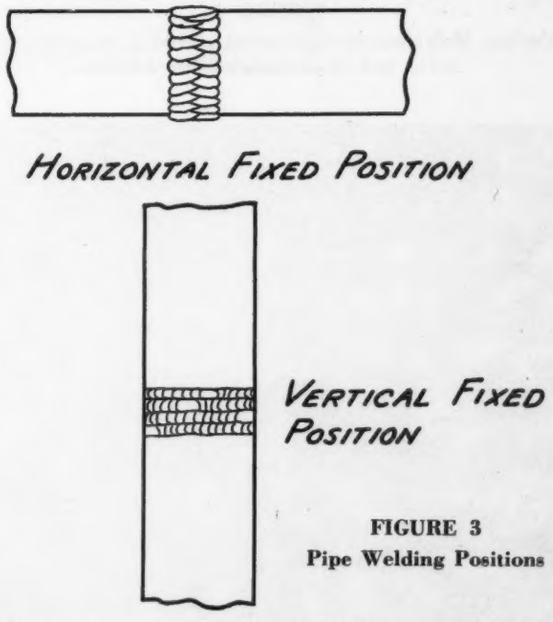


FIGURE 3
Pipe Welding Positions

F. have been recommended. Preheating to 400° F. appears to be adequate provided that this amount of preheat is carefully maintained throughout the welding operation. Each welded joint requires stress-relieving by heating to a temperature of 1200° F. to 1250° F. for 1 hour per inch of thickness after the weld is completed. And that is all there is to the welding procedure. The refiner is allowed a choice of conditions to suit his fabricating methods.

All that remains is the qualification of this welding process by having a welding operator follow the written directions to make a sample weld. Welds in both the horizontal fixed position and the vertical fixed position as illustrated in Figure 3 are tested for soundness, strength and ductility. Any welder who

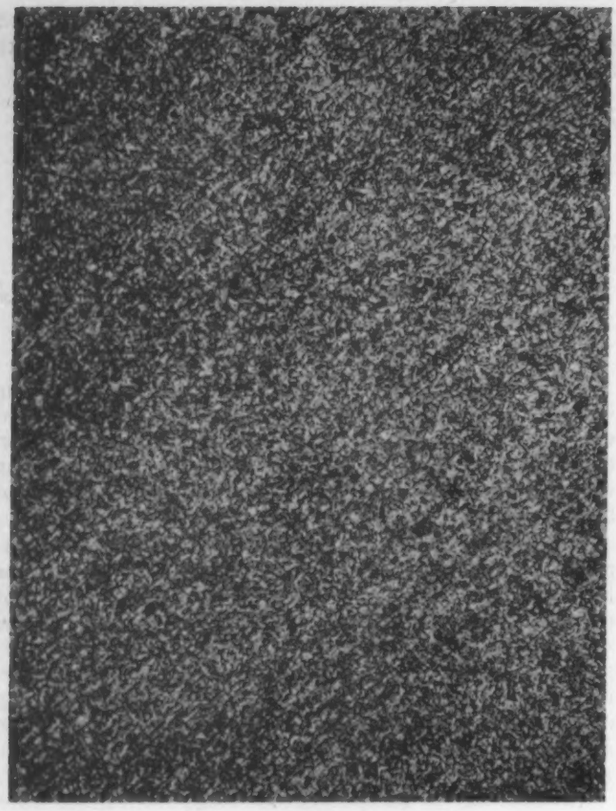


FIGURE 4

Carbon Molybdenum weld metal at 100X. Note the fine grain and cleanliness of the deposit.

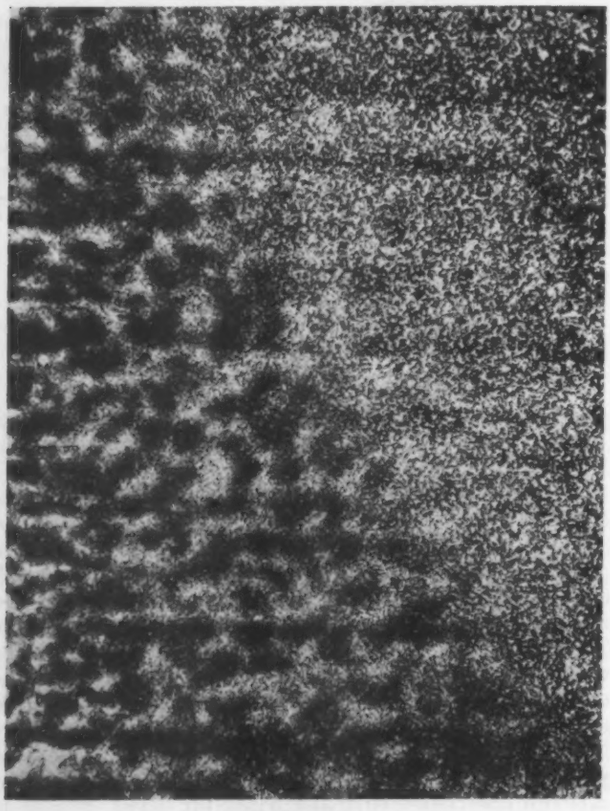


FIGURE 5

Juncture of weld metal and zone of grain refinement at 100X.

can make satisfactory welds in mild steel and who has passed code tests in such material will experience no difficulty with this qualification routine. Similar tests are made to quaify as many additional operators as will be required for the work.

The only point in which the welding procedure differs from that used in welding carbon-steel piping is in the matter of heat treatment. Preheating and stress relieving are carried on by means of portable electric or gas devices that are fastened to the pipe on either side of the joint. Thermocouples are used to indicate correct temperature throughout all heating cycles. Proper supervision is necessary at this point as it constitutes the most important phase of the operation after the operators have been duly certified.

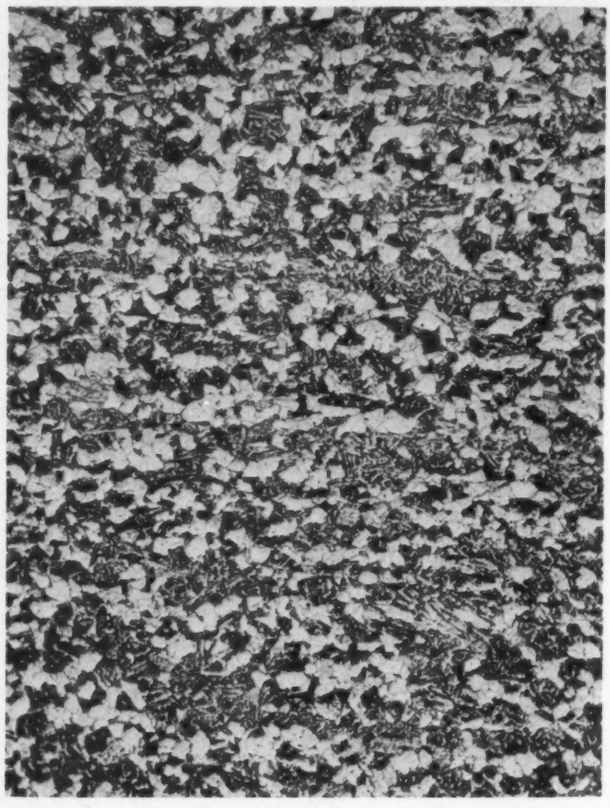


FIGURE 6

Carbon Molybdenum pipe at 100X

Adherence to both the letter and the spirit of the pressure-piping rules will result in a perfect job destined for years of trouble-free service. The adoption of carbon-molybdenum steel for high-temperature installations combines the utmost economy with extreme safety. Thus it is little wonder that so many recent installations have been made of this material. Soundness of weld metal is indicated in Figures 4, 5 and 6 where weld and pipe structures are shown. Service installations of long duration have proved the compatability of molybdenum bearing piping with excellent service in welding piping applications that demand high temperature operation for utmost efficiency.

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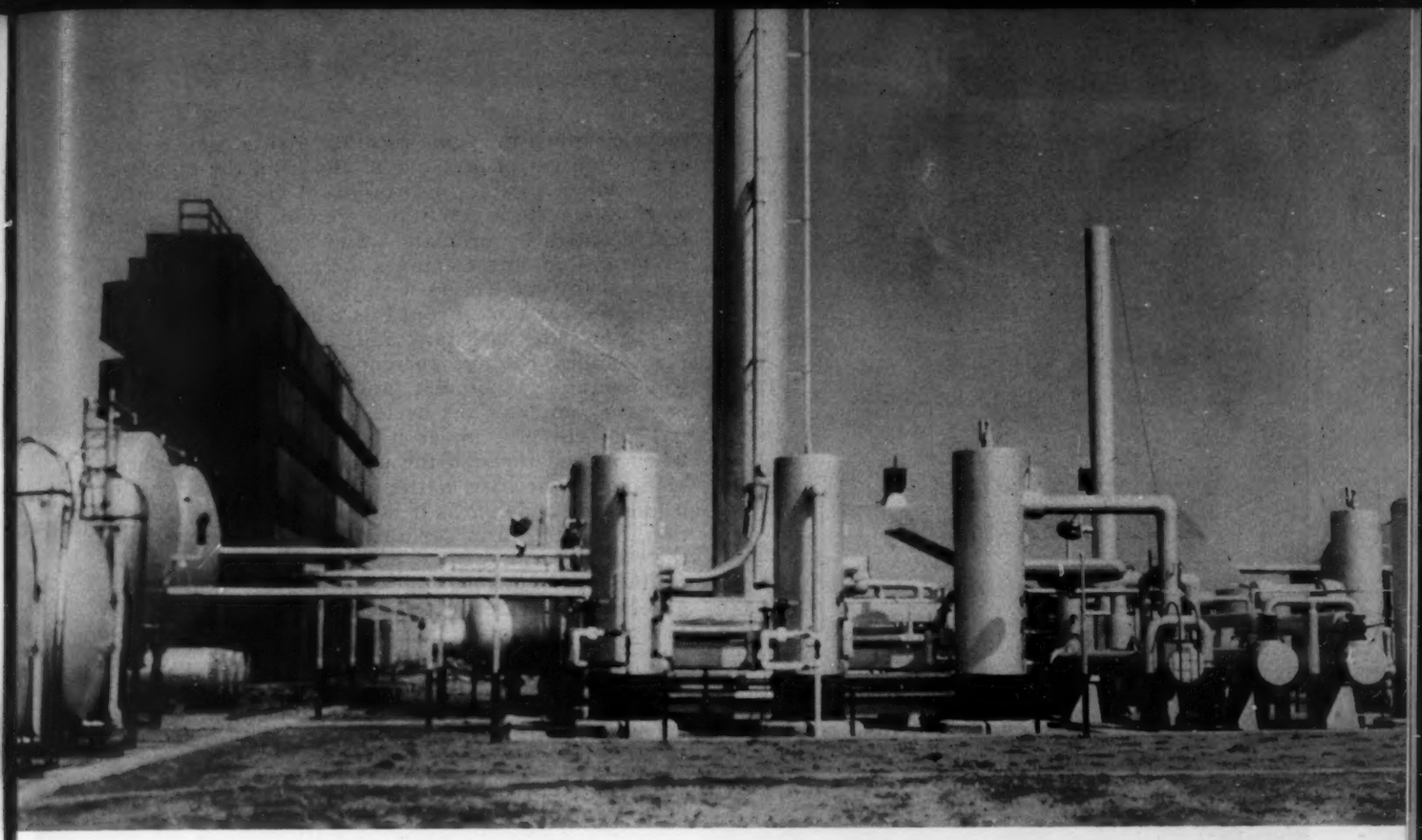


Refrigeration and Dehydration Fit Plant Into Repressuring System

IN ORDER to fit natural gasoline manufacture into the repressuring program of the K-M-A field, Wichita County, Texas, Continental Oil Company has restyled its main plant in that area. Natural gasoline extraction is accomplished by compression and refrigeration, while dehydration by diethylene glycol serves to reduce the dew point of residue gas to 8° F., which prevents freezing of equipment at input wells.

Both refrigeration by circulation of butane and dehydration with diethylene glycol have been used previously in gasoline plant operation. In this instance the butane system is similar to that used in reducing temperature of absorption oil. Previously, however, diethylene glycol has been used to remove hydrates from dry well gas or on residue plant gas, prior to delivery to pipe line systems. In the new plant at K-M-A the diethlylene glycol is introduced into the combination of compressed gases and condensate and is a part of the stream, which is reduced to 0° F. by circulation of the propane stream.

In addition to the refrigeration and dehydration units, additions to the plant consist of a new fraction column and auxiliary equipment for bringing finished products to specifications. This fractionation equipment also serves two other natural gasoline plants whose raw products are pumped to the central plant.

Three stages of compression are used. In the first gas is drawn from the field and boosted to around 40 pounds, gauge. In the next it is increased to 300 pounds, while the third is to 1800 pounds for formation repressuring.

The first stage is typical gasoline plant practice, drawing the gas through the gathering system at the field pressure, and boosting it to 40 pounds, gauge. The gas is cooled in atmospheric sections set in a water cooling tower and scrubbed to remove liquids produced. The condensate accumulated in this stage consists of high-boiling fractions which are combined with final production for further processing. No attempt is made to reduce the temperature of the gas at this low pressure below that obtained in conventional atmospheric-section cooling, and the gas is then picked up by the intermediate cylinders which raise the pressure to 300 pounds, gauge. The intermediate cooling is accomplished in atmospheric cooling sections, and the gas and condensate then enter the refrigeration and glycol dehydration units without separation.

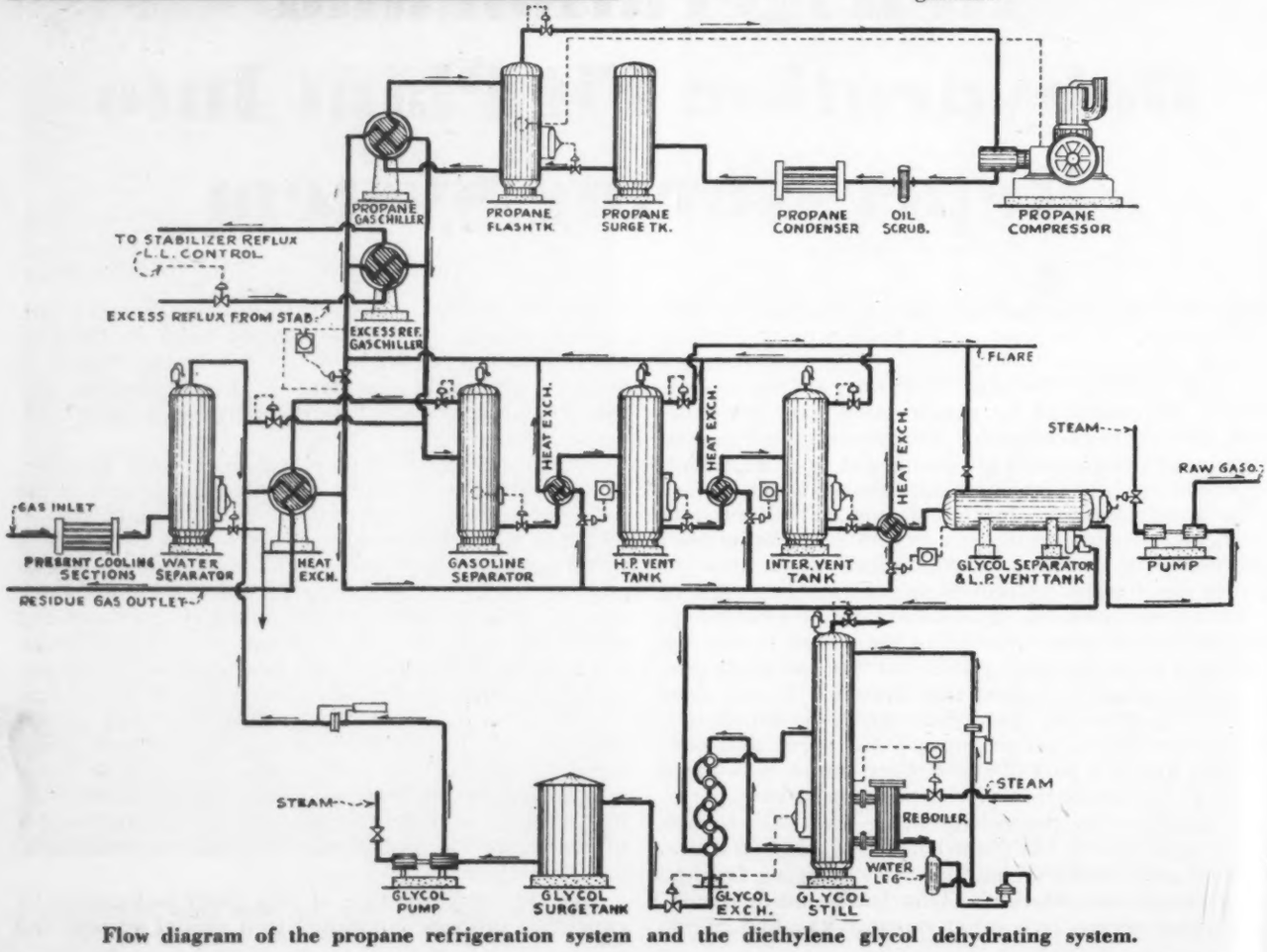
The refrigeration side of this plant is handled by expanded propane contained in a closed system and

recycled much the same as other plants use i-butane or a rough cut of propane-butane from the stabilizer reflux when cooling absorption oil and commodities when atmospheric conditions are unfavorable for low temperatures by ordinary water cooling. Two horizontal gas engines compress the gas and deliver it to atmospheric condensers with the liquid product passing to a surge tank. From this tank, the liquid passes to the propane flash tank and from there to the propane chiller, counter current to the stream of gas, gasoline and glycol, and thus, when returned to the engines completes the cycle.

This field gas, under a pressure of 300 pounds, when passed through the usual type of atmospheric sections in the base of the cooling tower, is handled in the same manner as it was during previous operation, but, instead of separating the condensate from the gas by turning the residue into the intake header of the repressuring engine cylinders, the liquids, gasoline and water and the uncondensed gases flow to a water separating tank which is equipped with an interface level control to drain out the water but not the gasoline. Under normal plant and atmospheric conditions this combination is at about 90° F, when it flows from the water-separating vessel through an 8-inch line to an exchanger opposite in flow to the stripped residue.

At the entrance to this exchanger, the liquid concentrated diethylene glycol is introduced at the rate

Vent tanks and separator, where pressure reduction is accomplished while constant temperature of zero F. is maintained previous to removal of diethylene glycol from raw gasoline.

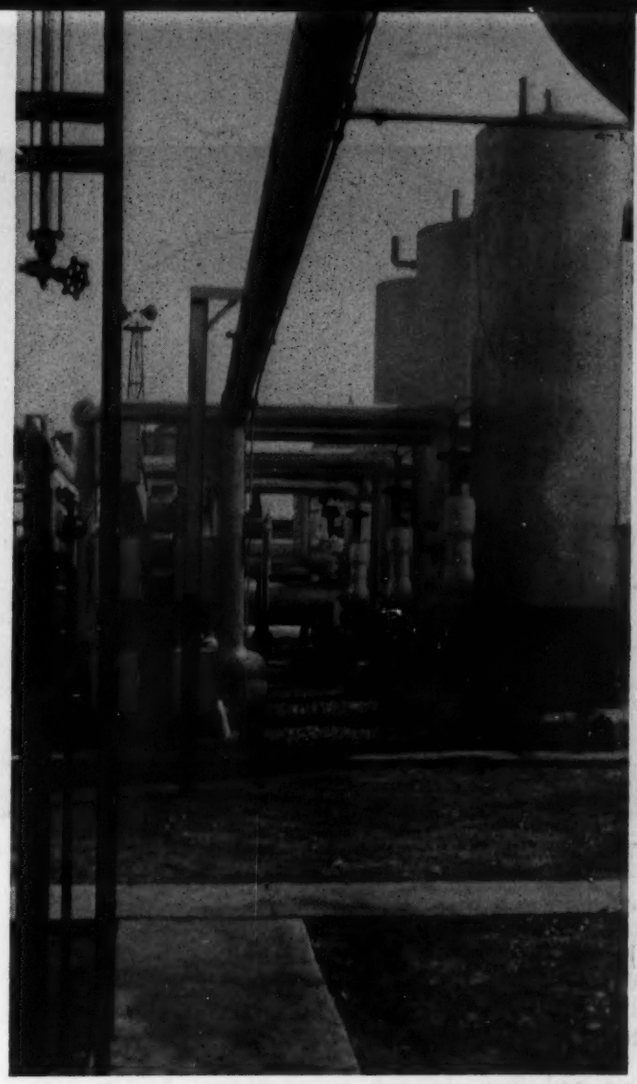


Flow diagram of the propane refrigeration system and the diethylene glycol dehydrating system.

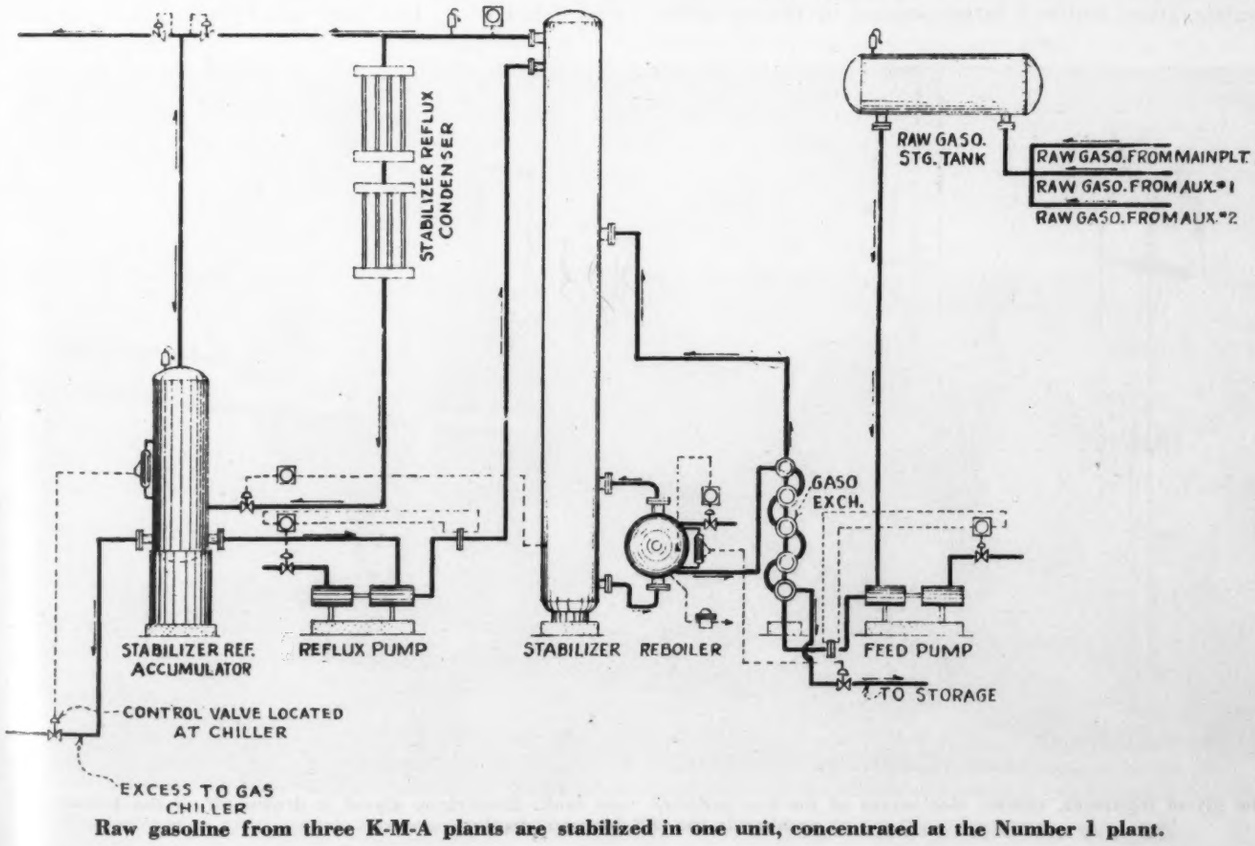
of 3 gallons per minute, directly into the commodity, instead of in a bubble plate contactor as used when glycol is used with dry gas. Since all condensed water vapor liquifiable at 90° F. and at a pressure of 300 pounds has been removed through the operation of the water-separating tank, the remainder is that which has been absorbed by the gasoline and that which yet remains in the gases. As diethylene glycol has a great affinity for water it immediately takes up the remainder quickly, and when diluted with water, has a freezing point well below 0° F.

As the function of the refrigeration system is to reduce the temperature of the commodity to 0° F., the uncondensed gas is at that temperature after the liquifiable hydrocarbons have been removed. Thus, by passing the residue gas through the exchanger counter flow to the incoming commodity, the temperature is reduced appreciably in the gas exchanger, down stream from the point where the glycol is introduced. Because of temperatures, extremely low when compared with temperatures ordinarily obtained in the average gasoline, the commodity could easily be hindered in passage if the small quantities of water were left in the original form. But, with the glycol to absorb it, the freezing point is lowered so much that difficulty is not encountered by the deposition of ice within the chilling system.

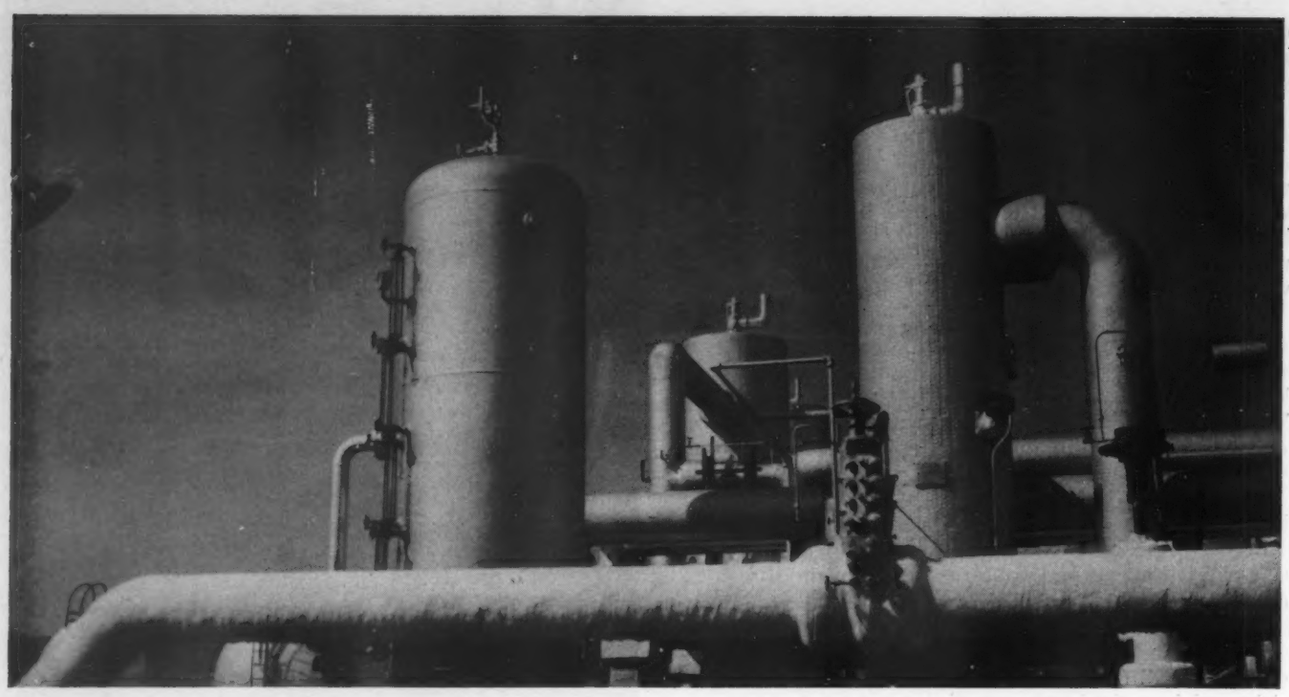
At the outlet of the residue gas exchanger, the stream splits in two, one flowing toward the propane chiller, and the other toward the vessels for reduction of pressure on the gasoline and to remove volatile gases. The stream passing to the vessels



Lines carrying combined product to glycol separator.



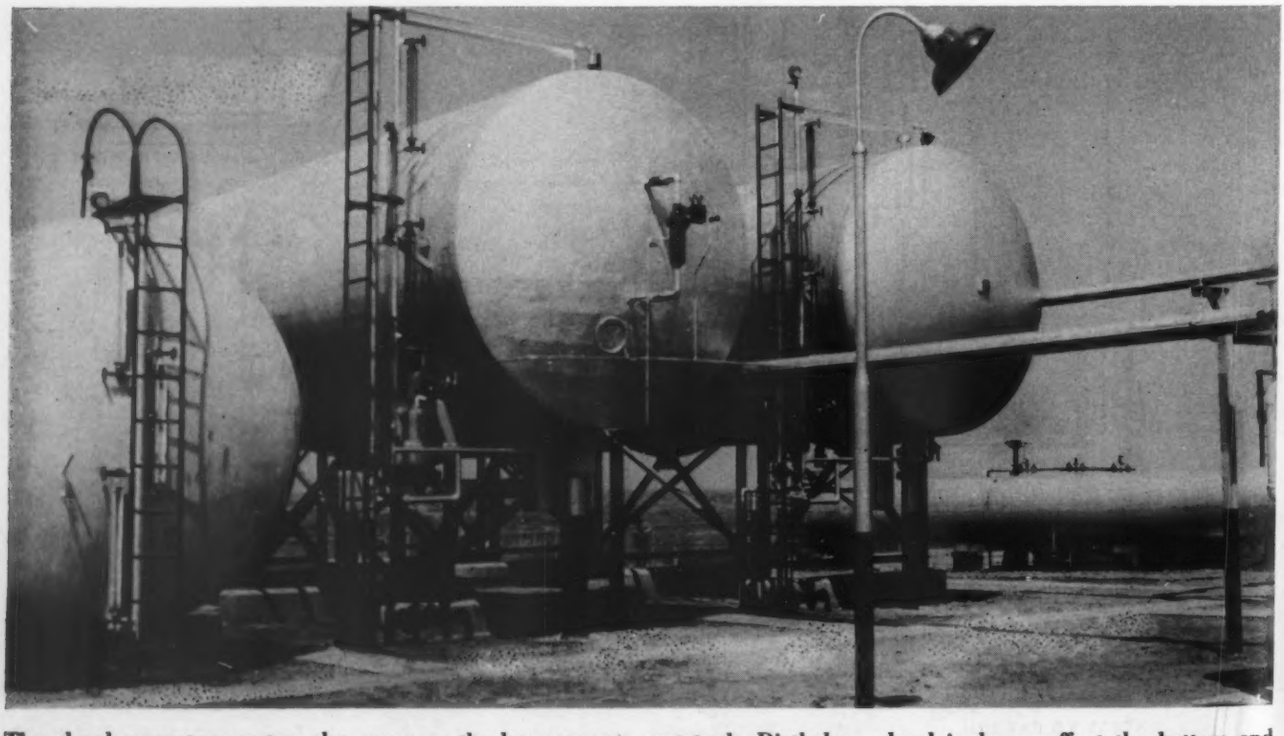
Raw gasoline from three K-M-A plants are stabilized in one unit, concentrated at the Number 1 plant.



Vessels in the refrigeration system are the surge and flash tanks, above. In the foreground is the plant vent meter run.

used for pressure reduction joins the first so that both are chilled to a uniform 0° F. When the temperature has been lowered on the gas, gasoline and the glycol, the composite stream flows to the gasoline separator from which the dry gas is removed, passing to the exchanger described above.

All liquids are trapped out of the gasoline separator and flow through an exchanger to the high-pressure vent tank, held at a working pressure of 150 pounds, from which a large portion of the methane and ethane, held in solution with the gasoline at 300 pounds is removed. Due to the refrigeration properties of quantities of gasoline vented from 300 to 150 pounds, temperatures lower than 0° F. would prevail if not quenched with some outside means. The split stream from the residue gas exchanger is controlled in quantity by temperature-recorder controllers and a diaphragm valve so that the entire stream flowing to the high-pressure vent is not lowered below 0° F. The same arrangement is applied to



The glycol separator, center, also serves as the low pressure vent tank. Diethylene glycol is drawn off at the bottom and pumped to the still for regeneration.

the intermediate vent tank and to the glycol separator, so that the stream is maintained at a constant temperature throughout the process of pressure reduction. Pressures of 70 pounds and 35 pounds are held respectively on the intermediate vent tank and the glycol separator so that the undesirable vapors will be removed in successive stages.

By following the method of successive pressure reduction coupled with exact temperature control, the fractionation results in a nominal loss of i-butane and heavier fractions. The extraction of available hydrocarbons by compression and controlled refrigeration, based on analysis of the gas from the intermediate pressure compressors, and an analysis of the residue from the gasoline separator indicates a high degree of efficiency.

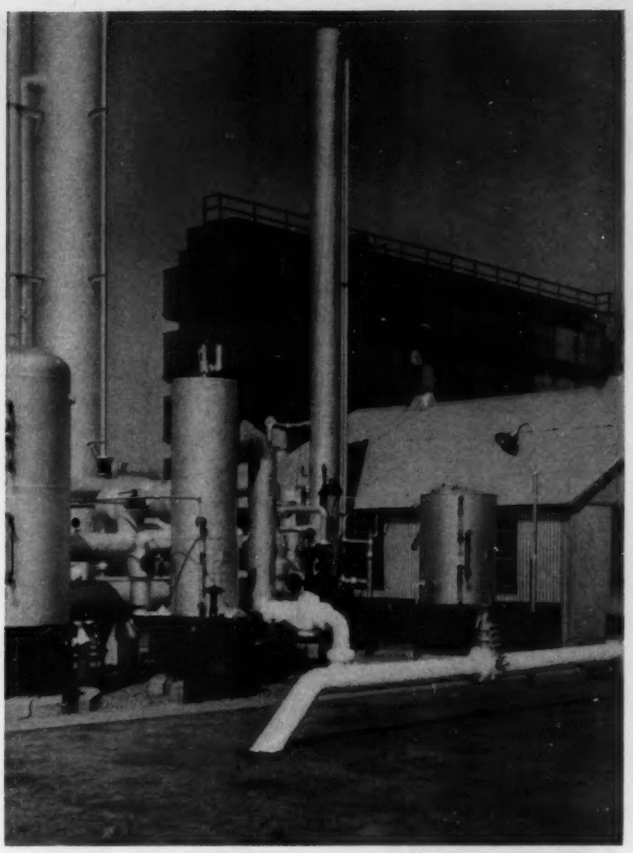
The glycol separator is a 10- by 40-foot horizontal vessel mounted on a steel structure above the ground level and insulated. Both gasoline and glycol flow in at one end, and out at the other. Separation of the two is accomplished by settling. The gasoline leaves the separator by flowing over a wier at the outlet end. The glycol is drawn away through a liquid-level controller from the lowest point in the tank and passed to the glycol concentrator, consisting of a conventional still, reboiler and exchangers. This unit is operated at a pressure of 10 pounds and at 275° F.

Fractionation System

The raw gasoline, passed from the glycol separator is pumped into a fractionator surge tank together with gasoline from the two auxiliary plants. Plant No. 2 is almost identical in construction and operation and capacity to the main plant, except that it contains no steam generating equipment nor does it contain a gasoline fractionator. No. 1 plant is smaller and the dehydrating units are operated with activated alumina to reduce the dew point of the residue gas.

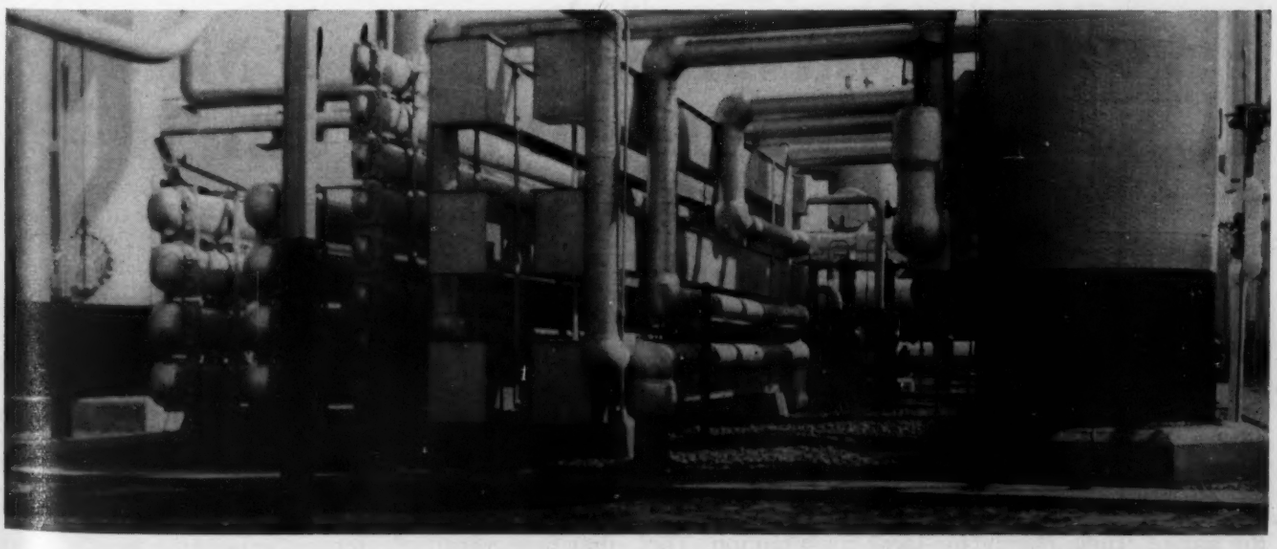
The main plant fractionator is similar in design to the usual type of gasoline plant column, but contains only one feed nozzle.

The combined feed from all three plants is fractionated together and may be cut to any grade required. It may be simply de-ethanized, debutanized, or a cut of propane may be removed from the overhead for refrigeration, and a fuel composed of propane and butane may be cut for use in drilling engines and for domestic consumption.

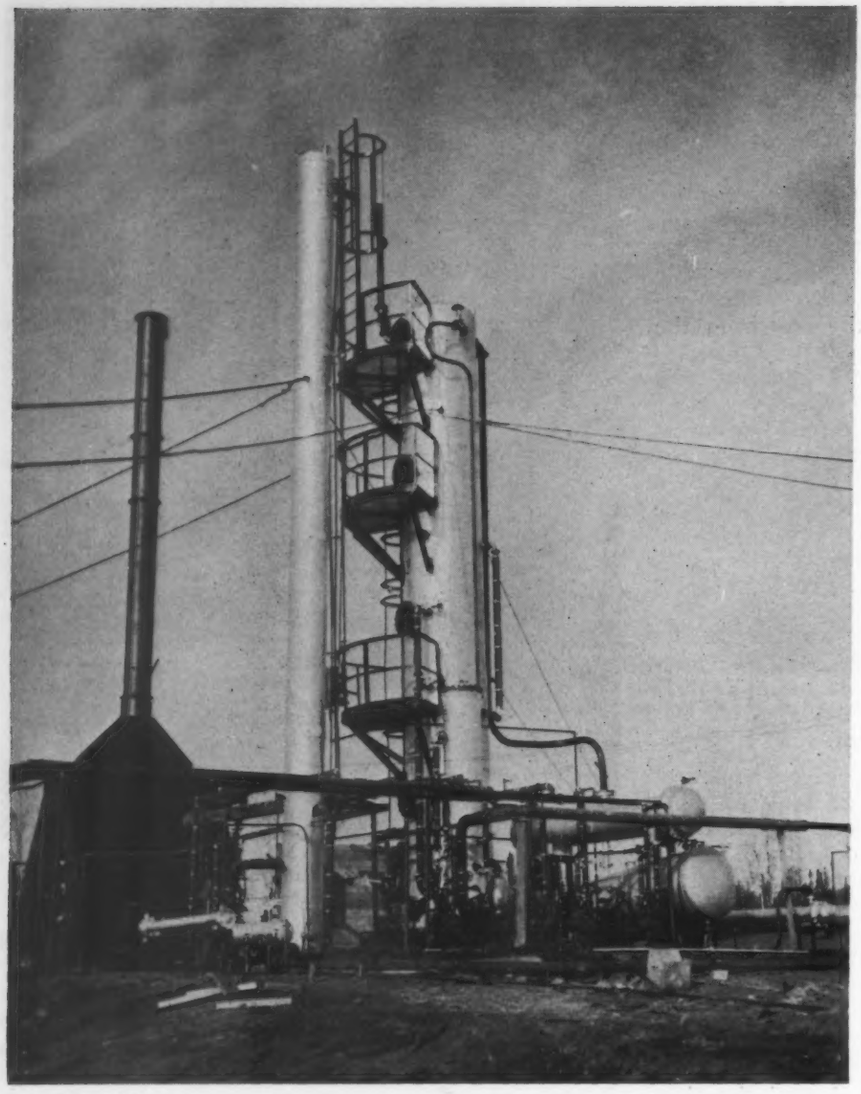


Diethylene concentrating still.

The gas after being processed for removal of desirable hydrocarbons, and contacted intimately with the diethylene glycol through the varoius stages has a moisture dew point of 8° F. at 1800 pounds. This is sufficiently low to prevent any accumulation or formation of ice at regulators and on valves at wells where the pressure is dropped abruptly from 1800 pounds to any pressure required for injecting back to the producing sand.



Heat exchange units, which are concentrated between the vent tanks, right, and the stabilizing unit, left.



The refinery at Norman Wells is simple yet adequate for Arctic conditions. Left to right are the heater, aviation gasoline cooler and reboiler, stabilizer, fractionating tower and pumps, overhead vapor condenser, reflux accumulator and final product coolers. The units are guyed to withstand high winds and frost-heaving.

Up Below The Arctic Circle Where The Mackenzie River Flows Down Toward The North Pole

Aviation Gasoline Is Being Made So Gold and Pitchblend Can Be Mined and Sent to Market

By RALPH E. PARKHURST, Foster Wheeler Corporation

THE most northerly refinery in the world has recently been completed by Imperial Oil Limited within 100 miles of the Arctic Circle. It is located at Norman Wells on the Mackenzie River in Northwest Territories, Canada, near Fort Norman, and consists of a combined distillation and stabilizer unit to refine the native crude, chiefly for local consumption. The unit has a capacity of 840 barrels a day and is unique in many respects—as might be expected due to its location.

The use of Fort Norman oil is a relatively recent development. The discovery well was brought in in 1920 but drilling was not pushed due to the fact that trapping of fur was practically the only industry at that time, very little demand existed for gasoline and fuel oil, and transportation was a major problem. In

fact, the wells were capped and drilling operations came to a standstill in 1925. The character of the district remained virtually unchanged until 1931 when Gilbert La Bine's eventful discovery of pitchblende made Great Bear Lake on the Arctic Circle the world's richest source of radium. This resulted in the rapid opening up of this district, beginning with Eldorado Gold Mines, Ltd., where the radium ore is mined and concentrated (see Heat Engineering, August, 1937). Since that time general activity has greatly increased and other precious metal mines, including rich gold ore, have been opened, such as in the Yellowknife area on Great Slave Lake. There is now a definite demand for aviation gasoline for the airplanes that regularly deliver mail, express and various mining and government personnel in the district, and for standard motor gasoline and Diesel fuel to run the engines in mines and river boats. Many of the residents, trappers, traders, dominion government officers, and missionaries require gasoline for their small boats, and gasoline is commonly used for lighting.

The wells at Fort Norman were reopened in 1932 and a small steam still, which had been set up in 1921, was operated to supply motor gasoline and Diesel oil for the local market, thus making it unnecessary to transport these fuels from rail head at Waterways, Alberta, to the various trading posts on the Mackenzie River. Hence a local refinery producing gasoline and fuel oil was of great economic importance. In the spring of 1932, the price of outside gasoline purchased from trading companies at Fort Norman Post, ranged from $2.00 to $2.50 per imperial gallon, depending on whether for cash or in trade. However, the Norman Wells gasoline was marketed during 1932 at 90 cents per imperial gallon and Diesel fuel oil at 25 cents per imperial gallon.

Practically all of the northern lakes and rivers are frozen tight during nearly 7 months of the year. The Mackenzie River at the Wells generally does not become free of ice until around May 25 and the last southbound boat of the season passes the Wells before the end of September. This results in limiting the annual operating season of the refinery to about 90 days.

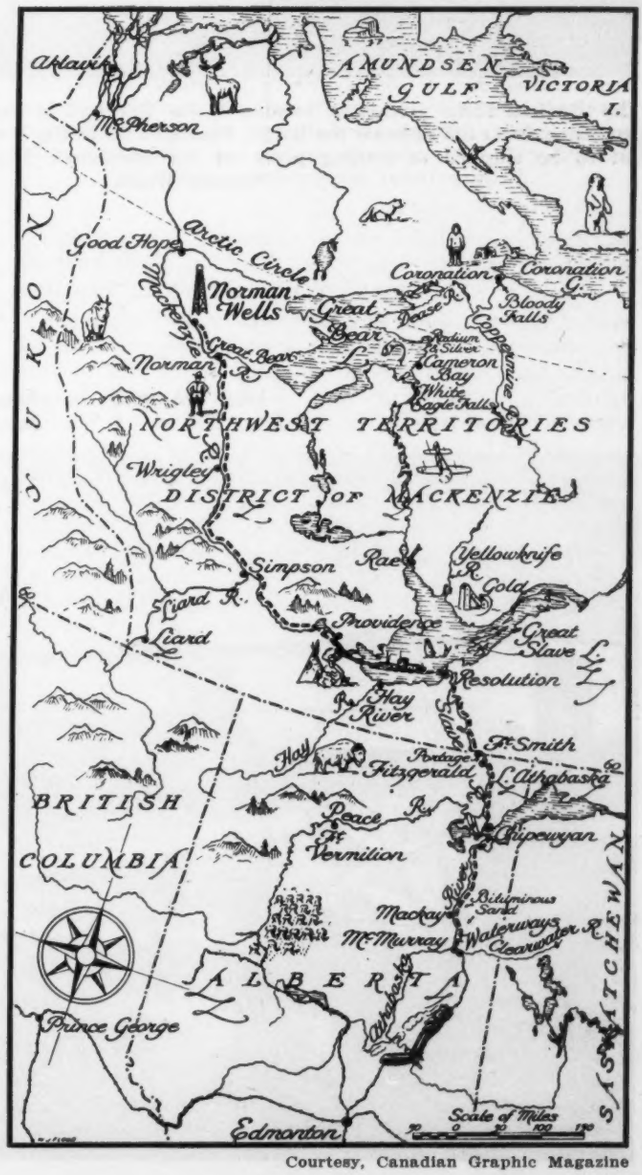
Transportation Governs Design

In designing a refinery for service at Norman Wells, transportation was the limiting factor. Equipment had to be shipped by rail across Canada from Foster Wheeler Corporation's shop at St. Catharines, Ontario, to Edmonton, Alberta, at a carload freight cost of about 2½ cents a pound, then by the Northern Alberta Railway to Waterways for an additional 1½ cents a pound. Here a transfer to barges was required for the long water journey down the Athabasca, Slave and Mackenzie Rivers to Norman Wells, at a further cost of 4 cents a pound. With transportation charges so high, it was important to use the lightest possible materials commensurate with the required strength and quality.

The means of transportation also imposed certain physical restrictions due to the size of barges and type of trucks operating on the Fort Fitzgerald-Fort Smith portage road—no single piece could be over 10 tons in weight nor occupy more space than 10 x 10 x 35 feet long. Some welding was done on pipe supports but generally all equipment had to be bolted, contrary to general practice. Maximum permissible pipe diameter was 4 inches on account of absence of facilities at the site for handling larger sizes. Some local lumber was available but the general use of wood was ruled out. Even gin poles for erection were shipped in. Because of scarcity of local skilled labor and a round trip transportation cost of $420 per man, and in order to reduce erection time to the minimum, it was necessary to assemble all equipment in the shop, so far as possible. Since Arctic weather conditions and open water would permit operation of the refinery only 90 days a year, the refiner desired as low an initial cost as possible for the installation, combined with low maintenance costs.

The main fractionating column was made in one piece, 35 feet long, with trays and caps bolted into place before shipment, to save local labor. Fabrication of the stabilizer column was from standard 20-inch pipe sections. The heater was assembled at the shop with tubes in place and then shipped in two sections. Special lightweight insulating brick was shipped in strong wooden cases. To reduce shipping weights,

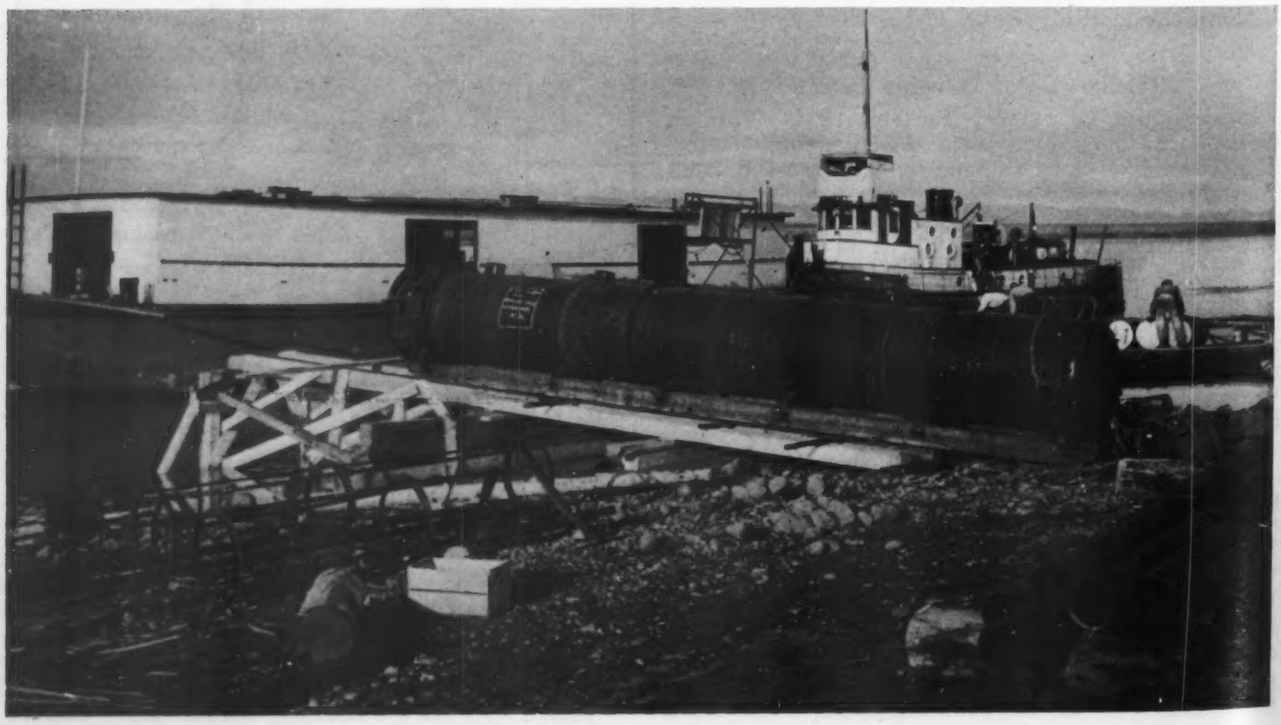
By rail to waterways, then by barge to Fort Fitzgerald, where began a 16-mile portage around the "Rapids of the Drowned," then back to barges for the distance down the Slave River, Great Slave Lake and the Mackenzie River to Fort Norman.



Courtesy, Canadian Graphic Magazine

The 'Radium King' arrives at Norman Wells. One end of the fractionating column is projecting from the door on the barge. Packaged oil in the foreground was some of the last to be shipped to trading posts on the Mackenzie River, north and south of Norman Wells.

After unloading the tower to the staging, the barge was moved to load the drums of gasoline and fuel oil for the trading posts.



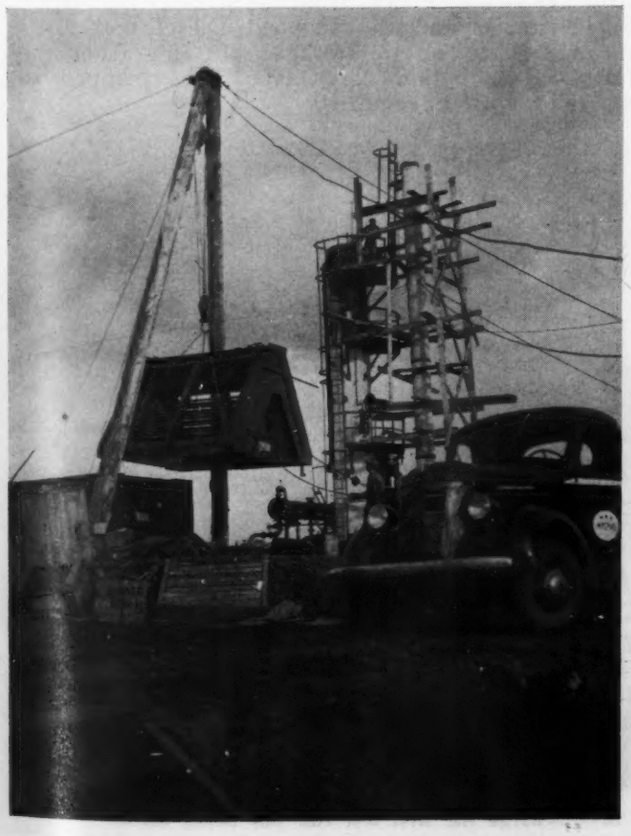
operator's platforms for attaching to the side of the tower were made of open grating instead of checker-plate. Because the water for condensing and cooling is taken from the Mackenzie River, which carries considerable silt at high stages, the shell-and-tube units were designed for high velocity of the water to minimize fouling, with relatively high allowable temperature rise to keep the water requirements as low as possible.

Rail, Truck and Barge

The journey of the equipment by rail to Edmonton was relatively uneventful. At Edmonton the cars were switched to the Northern Alberta Railway for the 300-mile journey north to rail head at Waterways. The shipment was skidded direct from the railway cars to barges on the Clearwater River and taken 300 miles down the Athabasca River past Fort McMurray and the tar-sand deposits, across Lake Athabasca, and then by the Rocher and Slave rivers as far as Fort Fitzgerald, near the northern boundary of the Province of Alberta. At Fort Fitzgerald a 16-mile portage had to be made to Fort Smith, using heavy trucks to circumvent the unnavigable waters of the "Rapids of the Drowned" on the Slave River. At Fort Smith the equipment was loaded onto other barges and pushed for 820 miles by shallow-draft river boats down the Slave River to Fort Resolution on Great Slave Lake; thence across Great Slave Lake, which is the source of the Mackenzie River; down this wide majestic river past Forts Providence, Simpson, Wrigley, and Norman, to be finally unloaded at Norman Wells, 53 miles north of Fort Norman on the east bank of the Mackenzie River.

The Norman Wells site, showing crude storage tanks as well as drums awaiting shipment. Some of the vessels are lying on the slope while the tower is being dragged ashore. Within a few weeks after this picture was taken the plant became the world's northernmost refining plant.

Erection of the heater was simplified because it was shop-assembled in two sections with the tubes in place. At the site it was necessary only to set the top section over the base, bolt them together and install the brick insulation. The truck has the distinction of being farthest north in Canada.



The frost line at the Wells is about 50 feet below the surface, dating back to the Glacial Age and, of course, the ground below never thaws out. Each spring, where there is any moisture, the soil is inclined to heave, and becomes extremely spongy where disturbed. In preparing the ground for the site very difficult conditions were encountered. It was necessary to remove the heavy moss which is from 8 to 12 inches thick, in order to permit the frozen ground beneath to partially thaw out. Then the upper layer of 6 to 8 inches could be scraped off and the rest allowed in turn to thaw. Grading was carried out in a veritable quagmire which became so bad that the tractor had to move off to firm ground and drag the slip scraper by means of a long drag line and tackle. To support the heater, fractionating tower and stabilizer under these conditions, grillages of steel members were constructed like a mat under each one, extending well beyond the edges to prevent tipping. Additional support was furnished by guying the two towers and the 35-foot stack. Foundations were dug down through the fill, into the frozen ground and filled with river boulders and gravel.

The heater was bolted together after swinging the two shop-assembled sections into place and the whole was made rigid by cross-bracing. Instead of using firebrick for the floor of the heater, it was covered with local clay 18 inches deep and is probably unique among oil heaters in this respect. In order to save other materials and yet obtain the necessary elevation, the small vessels and piping were supported with driftwood timbers and welded sections of 4-inch and 2-inch pipe. A house was constructed over the various

pumps by a carpenter who was left at the Wells when the refinery crew departed for Calgary on September 27. (This carpenter did not leave until the middle of December on the first winter plane.)

Uncoupled for Winter

All interconnecting piping is uncoupled each year to prevent damage by the frost heave. All equipment was realigned in the spring of 1940, but extensive realignment would not be anticipated in the years following, due to the fact that the actual ground on which these river boulders and foundations are set would not be expected to thaw out during a summer season. All instruments are likewise disconnected and stored during the winter. It was essential that they should be as simple and foolproof as possible, of direct-acting mechanical types, as no service facilities are available closer than Calgary, Alberta.

Water pumps are not permanently set and must be shifted as necessary to meet the 6-foot difference between high and low water level in the Mackenzie River that supplies water for the refinery. In fact when the ice goes out in the spring, the water and ice build up to about 30 to 40 feet above normal water level, and debris in places is spread 250 feet inland from the normal water's edge. Due to this fact all docks, gasoline and oil delivery lines for river boats, also water lines from and steam lines to the pump house have to be dismantled and hauled up on top of the river bank proper before the crew leaves for the outside. On the arrival of the refining crew the following spring, around June 1, all this class of equipment must be replaced and this is the first job that must be done before the start of actual refining.

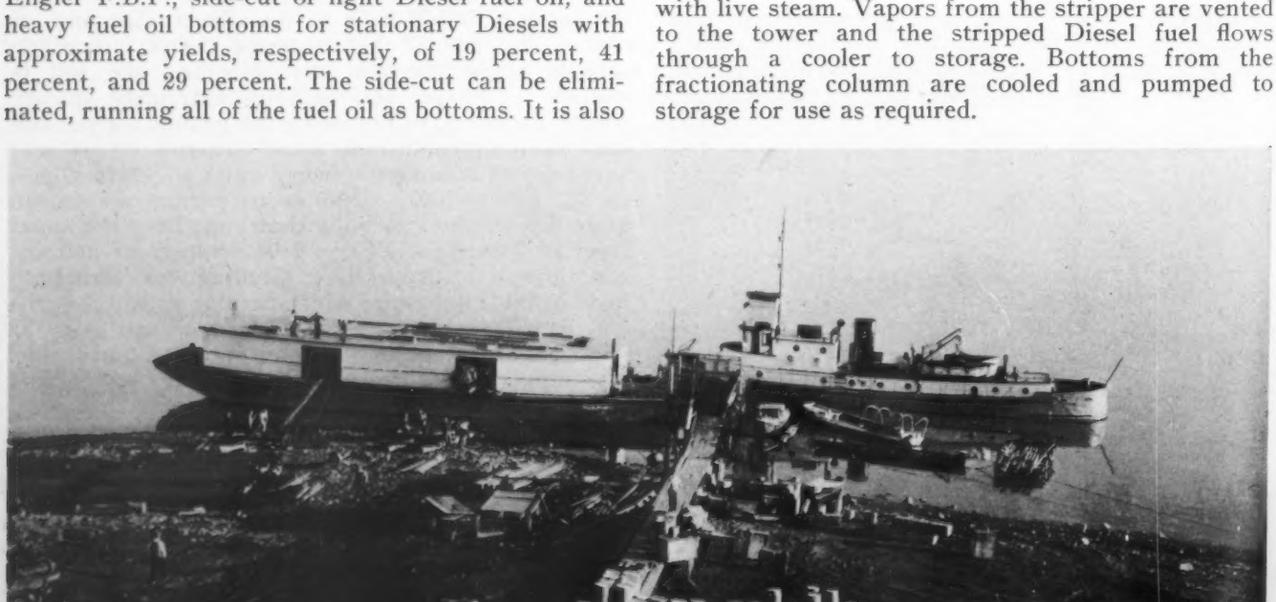
The plant was designed for three alternate operations, producing a stabilized gasoline of 270° F. Engler F.B.P., side-cut of light Diesel fuel oil, and heavy fuel oil bottoms for stationary Diesels with approximate yields, respectively, of 19 percent, 41 percent, and 29 percent. The side-cut can be eliminated, running all of the fuel oil as bottoms. It is also possible to run a 400° F. end point motor gasoline overhead and take Diesel fuel oil as bottoms.

No Preheating

The crude charge is introduced directly into the convection section in the upper part of the heater, without the use of any heat exchange equipment, and is brought up to temperature by firing a combination oil and gas burner. Omission of exchangers to preheat the charge is unusual but an economic study indicated that they could not be justified, due in a large part to the high freight charges. The heated oil flows to the fractionating tower where it is flashed at a point near the bottom. Live steam is used for stripping. Overhead vapors are condensed in a water-cooled condenser and collected in a combination reflux-accumulator and water separator. Any remaining vapors are vented from this drum into the refinery fuel system. Part of the condensate is returned to the top of the tower as reflux to control the temperature at the top of the tower.

The net overhead may be pumped direct to storage if 400° F. end point motor gasoline is the desired product. Normally, however, the net overhead is pumped to the top of the stabilizer column. This column is of the charge reflux type in which the feed flows down from the upper part of the column. Although this stabilizer has slightly higher losses than the usual type, it was selected in this instance for its simplicity. The heat required for stripping in the stabilizer is obtained from a steam-heated reboiler. Gas is vented from the top of the column to the refinery fuel system. Bottoms consisting of stabilized aviation gasoline are cooled and delivered to storage.

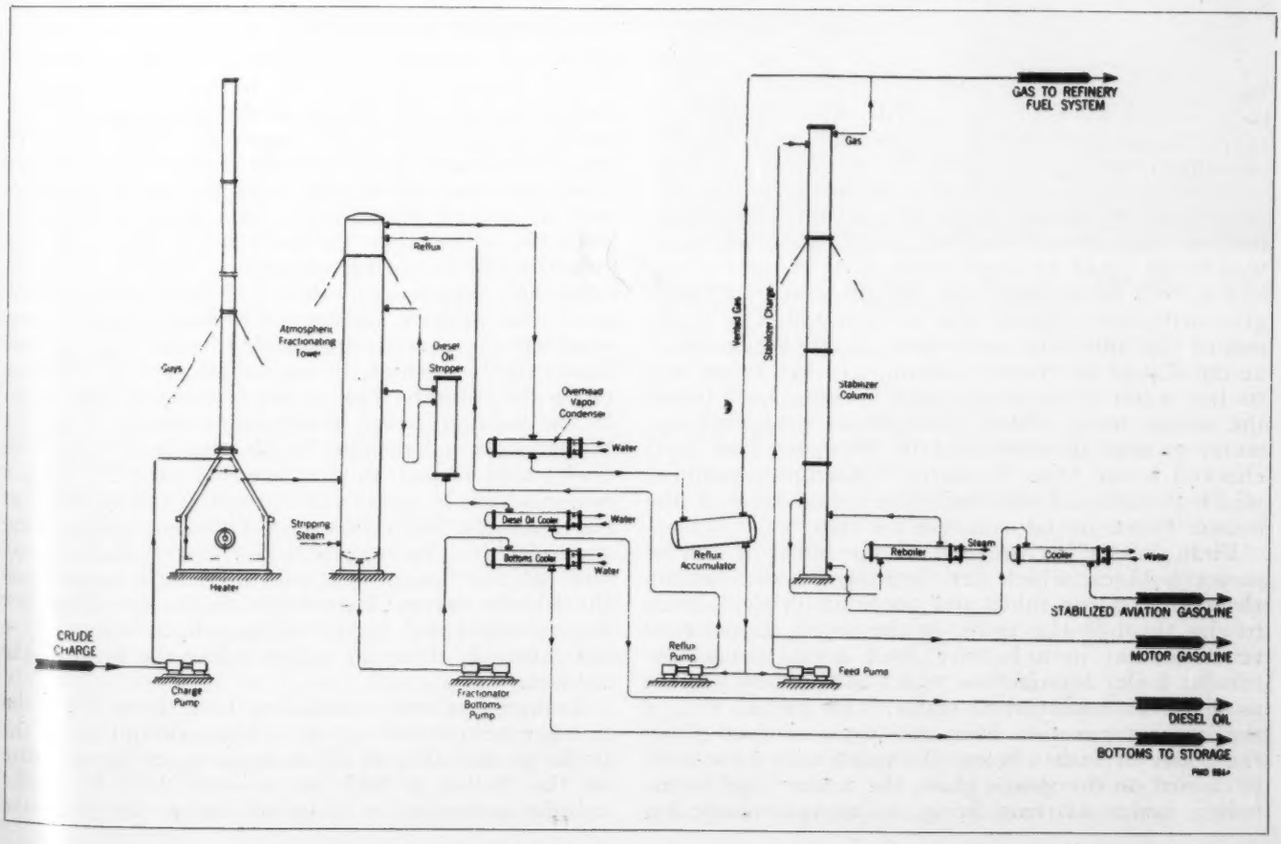
If a light Diesel fuel side cut is to be run, the stream is conducted to an external stripper operated with live steam. Vapors from the stripper are vented to the tower and the stripped Diesel fuel flows through a cooler to storage. Bottoms from the fractionating column are cooled and pumped to storage for use as required.

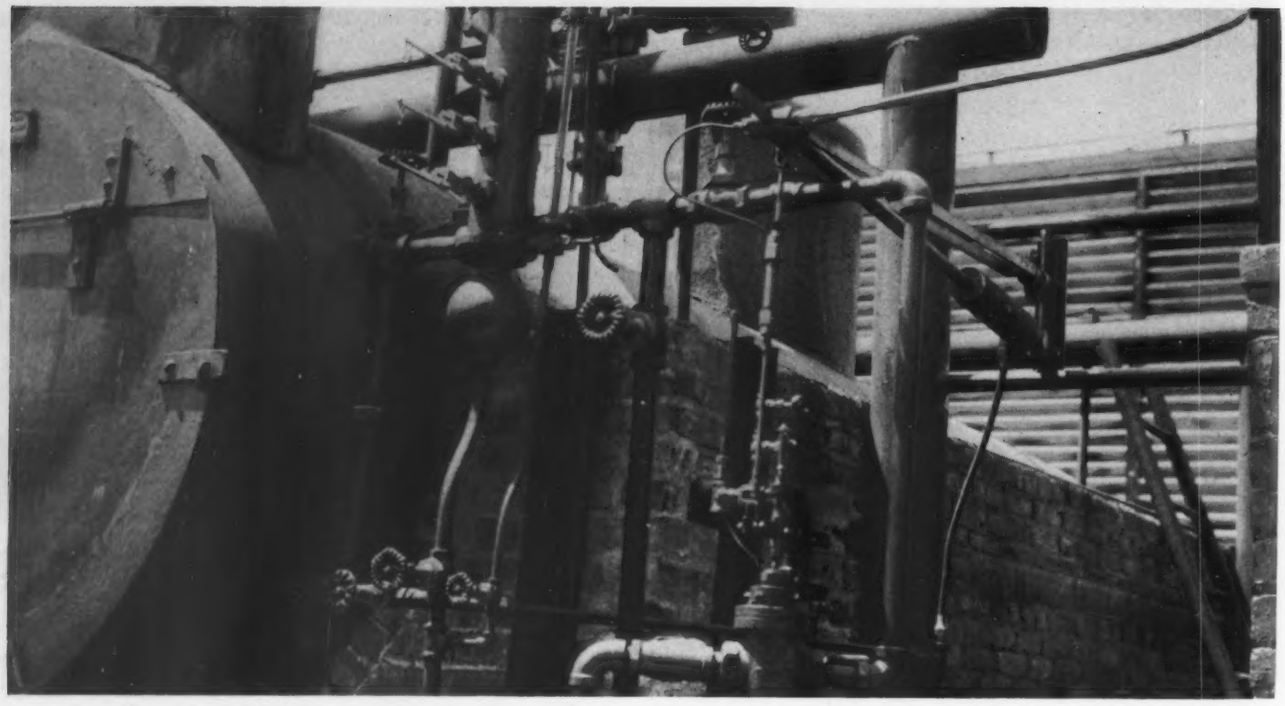


Thirty days after the tower was taken from the side of the barge the first test run was being made.

Boards that formed the crates in which the refinery equipment was shipped, were converted into a needed addition to the warehouse. Motorboats like the one at the right must be pulled up a vertical distance of about 60 feet from the water's edge in the fall in order to be safe from the debris that piles up from the choked river in the spring thaw.

Only 30 days elapsed between the time the equipment arrived at Norman Wells and the time the new refinery was put on a test run. The local requirements for standard motor gasoline and fuel oil for part of the Yellowknife mining area, Great Slave Lake, Mackenzie River Valley and the mining area on Great Bear Lake are now and have been supplied since 1932 from the Norman Wells refinery. With the Foster Wheeler unit erected in the fall of 1939, the Norman Wells refinery will be marketing products in 1940 such as Intava Ethyl 87-octane and 80-octane light Diesel fuel oil, and probably a bunker "C" heating oil, in addition to standard gasoline and heavy fuel oil. Due to the new refinery, motor gasoline can now be purchased in 90-gallon lots at 32.4 cents per imperial gallon, in contrast with the 1932 price of $2.50 per gallon. Heavy Diesel oil was marketed at 14.04 cents per gallon, f.o.b. Norman Wells, during the season of 1939. Although this new plant represents no great advance in the art of refining, it does indicate the value of the experience gained from far more complicated arrangements to produce a simple and conservative unit design to meet the peculiar problems of Arctic refining.





Mounting of Regulator, Showing Method of Connecting to Valve Lever by Means of Shock Absorber.

A New Principle in Boiler Feed-Water Level Control

By J. A. CAMPBELL, Research and Development Engineer

SUBSEQUENT to the account (REFINER, February, 1937, page 60) dealing with work done at Lomita Gasoline Company's plant at Signal Hill, California, designed to better the results obtained from boiler feed-water regulators of the thermostatic-tube type, further experiments have been made. This first work was to set up an inclined brass tube, 48 inches long and ¾ inch in diameter and, alongside of it, a gauge glass with thermometer well at each end. The upper end of the tube was connected into the steam space at the top of the water column, and the lower end to the water column near the bottom, well below the water level. These connections permitted the water to seek its own level in the tube. This level checked lower than the level in the glass column, which is always lower than the actual level in the boiler. There are two reasons for this:

First. Water in the shell of the boiler is full of steam bubbles, which are forming on the bottom sheet and on the tubes and continually break loose to rise through the water in the boiler. Experience revealed that in a heavily fired horizontal-return-tubular boiler this frothed water is about 85 percent as dense as undisturbed water. This means that if the lower connection from the water column enters the boiler 22 inches below the point where the level is carried on the gauge glass, the actual level in the boiler, under extreme firing, is approximately 3¾ inches higher than shown in the gauge glass. Boilers equipped with water legs have been observed where the lower gauge column connection was well down into the leg. In one instance, affecting a battery of boilers, this gave a false level of 8 inches with the result that the boilers put out only wet steam, which is not surprising.

Second. Temperature has a decided effect. Firemen who operate boilers with float-operated low-level-whistle alarms, know that when the whistle blows for low water, it can be stopped by blowing down the column. The reason for this is that water in the column, being somewhat removed from the boiler, cools and shrinks. By blowing the column this cool water is lost and replaced by water from the boiler which is up to full saturated temperature of the steam at boiler pressure. This hot water, being expanded by the heat, will rise to true boiler level and lift the float of the alarm enough to shut off the whistle valve. Observation shows this difference to be about 1 inch in the ordinary h.r.t. boiler where the return is about 20 inches below the level of the column.

Assumption and calculation will show what the average temperature in the column should be. If the boiler is operating at 150 pounds, water temperature in the boiler should be around 366° F. If the column connected is 20 inches below the level, the

effect is a U-tube with one side filled with water at 366° F. to a height of 21 inches with the other side filled with water at a lower temperature and to a height of 20 inches.

The problem is to determine the water column temperature. The two columns weigh the same because they are in balance. Water at 366° F. has relative volume of 1.1363. Volume on the cooler side is 20-21 of what it is on the hot side, or 20-21 of 1.1363 which equals 1.08, a relative volume opposite 288° F. in the tables. It is reasonable that this column, being uninsulated and separated from the boiler, should be this much cooler.

These influential factors, often given scant consideration by manufacturer, operator and inspector, are on the safe side insofar as burning of sheets and tubes are concerned. But they are on the wrong side for the production of dry steam.

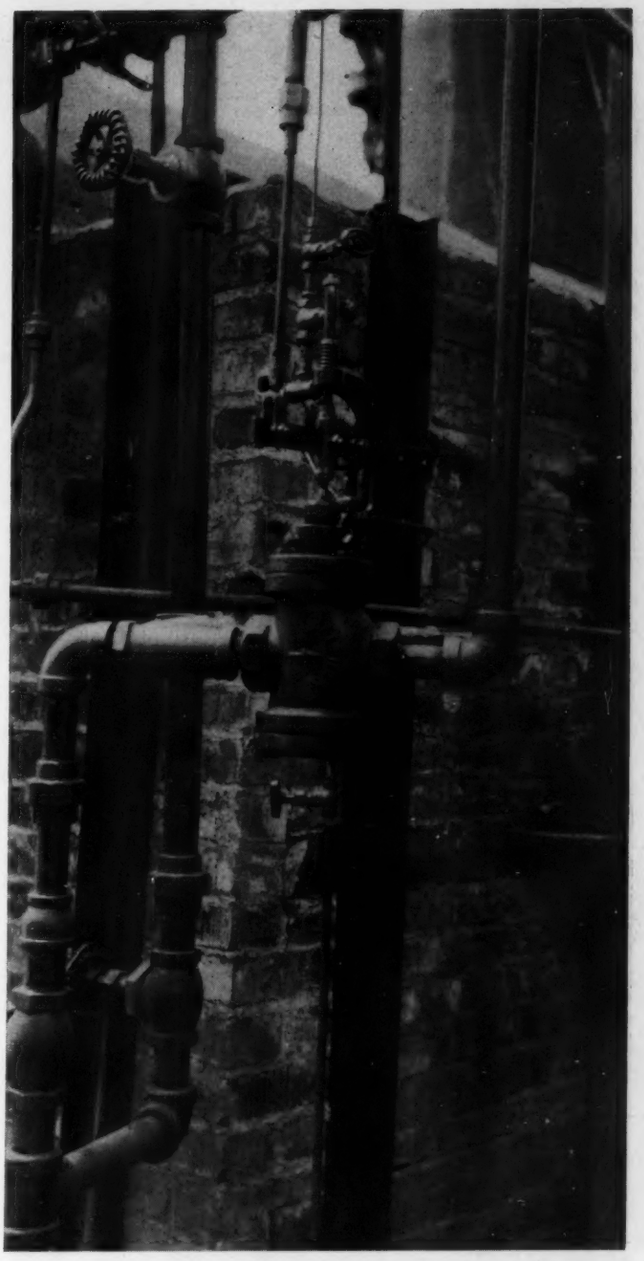
Fire-box boilers are favored in the oil industry because they give dry steam. One reason they produce dry steam is because the level shown in the gauge glass is very nearly the true level in the boilers, since the lower gauge glass connection usually is directly into the front sheet, making legs of U-tube short. Fire-box boilers, however, frequently blow up because they do not have that reserve of water above the false level shown in the gauge column.

The level in the long gauge glass paralleling the tube, previously referred to, checked lower than the level in the column. The lower temperature was responsible for this, since the return line from the regulator was small, ½-inch, permitting rapid cooling and remaining cooler because of being remote from the boiler. This left the level in the tube subject to weather changes.

Investigations

The first task with the arrangement was to keep the level as nearly as possible in the middle of the inclined tube by hand control and by observation of the glass tube alongside. Hourly readings were taken during 24 hours and the averages showed 366° F. for the upper end and 268° F. for the lower end. The first problem was to determine the reason for this slight difference. Two contributing factors were evident. First, the steam lead from the upper end of the tube was a small uninsulated line. This condensed considerable steam and the resulting hot water, having no other place to go, traveled down the tube, heating the lower end. Second, the upper end of the tube was in contact with steam. Brass being a good conductor, this heat went to the lower end of the tube and the only means of getting rid of it was through radiation from the small surface of the tube to the atmosphere.

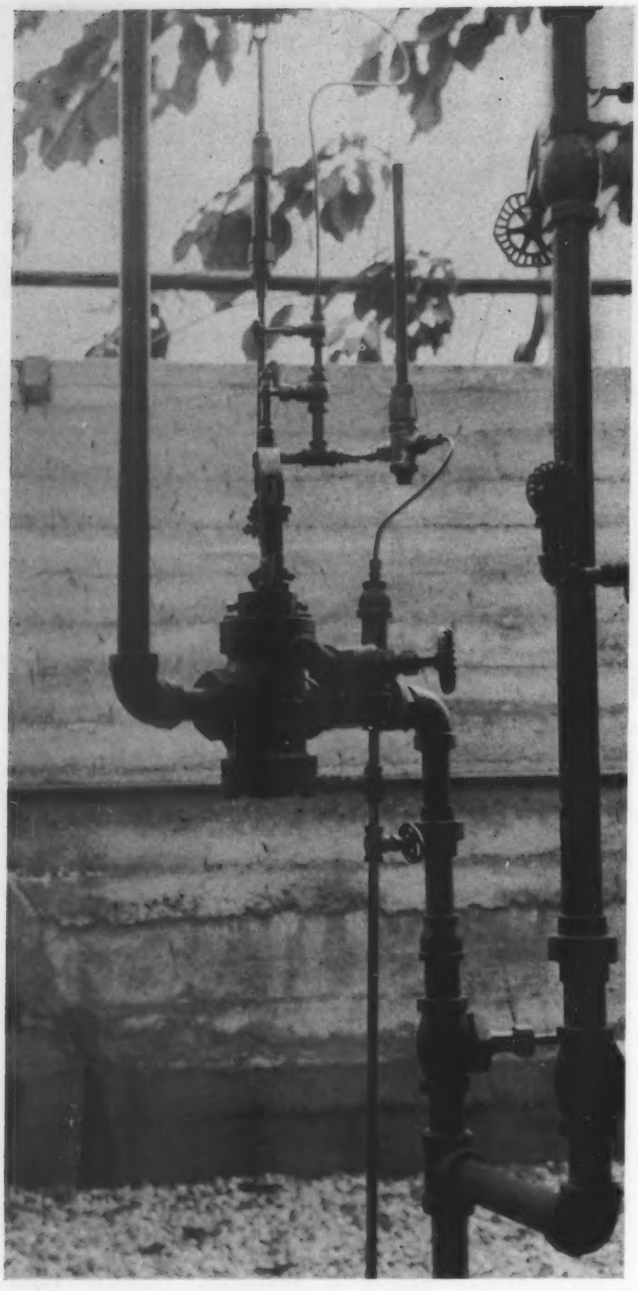
To correct this an upper end casting was designed with a drip pocket to catch the hot water, which was drained out through a connection near the bottom of the pocket then passing through a small copper tubing to cool it, then reconnecting it into the return water line, thus by-passing the tube. This change lowered the back end temperature 31° F. This was so encouraging that an intermediate casting with a drip pocket was cut into the tube just above the point where it was desirable to carry the water level. This drip pocket was then connected into the small copper by-pass line. Another 19° F. in temperature was gained in this by-passing of the condensate from the steam-filled upper end of the tube.



Showing Simple Method of Motivating Auxiliary Valve Controlling Cooling.

The second condition was corrected by finning the lower end of the tube to increase radiating surface. This lowered the temperature of the lower end casing approximately 100° F. All of this resulted in a very sensitive tube, which needed only a valve and method of valve motivation.

Elongation in an inclined brass tube caused by even a 1-inch drop in level is only a few thousandths of an inch. When directly connected to a valve stem, this small movement of the valve makes it necessary to use a large valve in order to get sufficient peripheral opening to pass sufficient water to restore the level. Using a large valve and opening it just a few thousandths of an inch tended toward liming up of the small opening where the water is poor. It is also conducive to wire drawing and cutting of the valve and seat. To secure greater valve travel and thus permit use of a smaller feed valve, the cantilever principle was adopted. This was applied



Thermometer Well Where Temperature of Feed Water is Taken.

by pivotally anchoring the lower casing to the stem of a T-bar. Six inches above this point another casting was pivotally anchored and two rigid bars attached to it. Other ends of these bars were pivotally attached to the upper end casting. This was accomplished by means of round, tapered lugs on the casting, which engaged round, tapered holes in the ends of the bars. The result was a rigid triangle.

Principle of a Triangle

It is a principle in geometry that a triangle, so long as its legs remain straight, can not be changed in shape without changing the length of one of the legs. When the tube gets hotter, due to falling water level, it lengthens. It can not lengthen along its own axis because of the restraining bar which remains of fixed length so the outer end of the tube must swing upward on the arc. This upward movement, due to the ratio of tube length to the spread between the two anchored ends, is six times as great as the actual increase in tube length due to expansion. The arc having a radius of 42 inches and the movement of the outer end casing along the arc being relatively small, for all practical purposes, must be regarded as a vertical movement. From cold tube to steam filled tube at 150 pounds pressure this vertical movement is 1 inch, so it is evident that there is plenty of action for valve motivation.

The lever of a single-seat lever-type valve was connected to the end casting to the lever by means of a rod embodying a shock absorber. This was a simple spring-and-piston arrangement to take up strain otherwise thrown on the valve when a boiler is shut down and the outer casting is down to an extremely low position. This strain goes into compression of the spring. Any lost motion is multiplied by the cantilever action. To counteract this possibility all pivotal joints were equipped with cone bearings.

These changes resulted in close and positive control of the level in the boiler and showed what could be accomplished by refinements. At this stage, however, there still was one objectionable feature, slow recovery after a blow-down of the thermostatic tube.

Tubes of all thermostatic types of controllers should be blown periodically to prevent formation of sludge, which decreases sensitivity. A blow valve to atmosphere is provided somewhere in the water return line between the lower end of the tube and the boiler connection. To blow the tube, it is necessary merely to open this valve and the steam, being more fluid than water in the boiler, will sweep down the tube, blowing out all water it contains. This water, having been isolated from the boiler, has cooled and it is this cooler water which by running up and down the tube decreases its temperature or permits it to rise. When this reserve of cool water is wasted to atmosphere and the blow valve is closed, hot water from the boiler rushes back into the tubes to a true boiler level so far as temperature is concerned. This hot water expands the tube and opens the feed valve wider. It takes several minutes for this hot water to cool by radiation and, in the interval that the valve is slowly closing, the boiler level will rise considerably. In the test set up the interval was 6 minutes and the water level rose 3 inches above normal with each tube blow. When a boiler is filling this rapidly its steam output is seriously curtailed and the burden is shifted to other boilers in the battery. If an operator blows all the regulators in rapid succession and a pump governor and automatic fuel governor are in operation, excessive pump speed and extremely heavy firing will result or steam pressure will drop.

By-Pass for Cooling

Some means of rapidly cooling the tube after a blow down had to be devised to correct this deficiency in this type of controller. The by-passing of a small flow of boiler-feed water through the tube first suggested itself. The assumption was that boiler-feed water, which in this case, was 190° F., would be so much cooler than the average temperature of the tube that it would have decided cooling effect. This was tested by tapping into the bottom of the feed valve body, which was up stream from the closure and putting in a closely calibrated valve and con-

necting to the outer end casting of the regulator with small copper tubing. It was necessary to insert a small filter ahead of this throttle valve to prevent clogging. When water at the rate of one pint per minute was passed through the tube, its cooling effect would contract the tube, closing the feed valve and keeping it closed until the level dropped about 1 inch in the gauge glass where it would level off under control. Shutting the water off would open the valve through heating of the tube and the level would build up to its former position. When blowing the tube the valve would come back to normal opening in 30 seconds. Capacity of the tube from normal water level to the back end was ⅓ pint, so the hot water which rushed from the boiler on the blow-down was quickly driven back. Also the cooling effect of the 190° F. water on the upper end of the tube which carried 366° F. temperature was pronounced.

The effect of this small stream of feed water indicated possibilities of further increasing sensitivity of the tube by controlling the amount of this cooling effect by automatically varying the flow. If sudden increase in the boiler load caused the level in the tube to recede and the feed valve to open, a decrease in the cooling flow through the tube should cause the valve to open farther.

A simple mechanism gave the desired control. A small slide valve, the stem of which was a vertical prolongation of the stem of the feed valve, was placed in the cooling water line after the filter. This valve was arranged to work in the opposite direction from the feed valve so that when the feed valve was opened the auxiliary valve was closing and vice versa. Since desired flow characteristics on the slide valve could not be had, although the principle proved sound, a change was made to a standard rotating stem ¼-inch globe valve. By selecting a pinion of proper size and substituting it for the wheel and putting it in engagement with the rack secured to the stem of the feed valve, exact flow control was provided. The amount of valve opening can for the purpose of meeting various differential pressures be quickly and easily increased or decreased by adjusting two nuts on the feed-valve stem. The adjustment is set so that when the feed valve is open to its fullest on the tube blow-down, the auxiliary will not entirely shut off but will still feed about ¼ pint per minute. Normal opening feeds 1 pint per minute and when the feed valve is shut off the cooling feed is 1½ pints per minute, which is insignificant in comparison with the amount per minute normally passing through the feed valve. Differential pressure under test conditions was 25 pounds.

Greater sensitivity is gained by this controlled cooling. The slightest opening of the feed valve causes a corresponding closing of the auxiliary valve, which in turn causes the tube to heat and further open the feed valve, which in turn further opens the auxiliary. The result of this multiplying and accelerating action is a quick and positive response through adjustment of level with no hunting. So much more movement is generated for a given change in level that valve movement has been reduced to ⅓ of the regulator movement which makes for more power and closer control. An extra heavy red brass tube has been adopted to delay response so as not to respond to surge or swell.

Because of the tendency to go to higher and higher pressures, an all-steel regulator was made, including a stainless steel tube. This brought equal sensitivity of control with a reduction of 2 to 1 instead of 3 to 1. This is a simple adjustment made on the valve lever.

After proving soundness of the principle under test conditions, there was one other question. What would be the effect on the controller of a varying temperature of the feed water? All tests had been under a range of from 170° to 190° F. Feed water often will vary 40° to 50° F. where there is variation in the load and no temperature control is used. To determine this effect, a 20-foot copper coil was put into the auxiliary cooling and run through an ice-water bath. This reduced the temperature of the auxiliary cooling water to 60° F. The only effect of this was to drop the water level in the boiler ½ inch below where it stood with 192° F. feed water. This slight reduction in level from a 132° F. reduction in feed water temperature proved that it would take a terrific variation in feed-water temperature to make any appreciable difference in operation of the controller. Also, elimination of dead water storage in the lower end of the tube by a continuous circulation of warm water has made the tube immune to fluctuations due to varying atmospheric temperature changes.

An additional advantage of controlled cooling is that the small flow of water down the tube tends to keep it free from sludge and makes it necessary to blow-down less frequently.

Effectiveness of this controlled cooling can be demonstrated by blowing the tube down by opening the atmospheric blow. In 20 seconds the feed valve will open ¼ inch. Normal feed opening is 1/32 inch. Close the atmospheric blow and in 50 seconds the feed valve will be back to normal opening and the boiler level will have raised less than ¼ inch; in 2 minutes it will be back to normal. On blowing down with the valve in the auxiliary feed line closed, the same opening will result but it will take 6 minutes for the valve to get back to normal. With the feed valve excessively open for this long interval, the water level will build up 3 inches above normal and it will take about 20 minutes to evaporate it back to normal.

Another demonstration can be made by changing the adjustment so as to shut the auxiliary cooling valve to one quarter of the way from normal opening to closed position. This will raise the level in the boiler ¼ inch. Cut the valve half way and the level will rise more than ½ inch. Shut the valve three fourths off and the rise is almost an inch. When closed the rise is 1 inch.

Another demonstration comes by shutting off the auxiliary cooling stream and by closing down on the feed valve adjustment, bringing the level in the boiler down to where it is normally carried when cooling is on. On blowing the tube the valve movement will be ⅛ inch, four times normal opening. With the cooling on the movement is ¼ inch.

The reason for this is that with cooling on, the end casting is depressed twice as much at normal level as it is with cooling off, so from this position it has twice the movement when the tube is blown. It must be remembered that valve movement is only a third of end casting movement.

This increase in valve movement adds a safety factor to boiler operation, since it is practically impossible to get low water if the differential is maintained and the supply does not fail.

Mixed Catalysts

By VLADIMER N. IPATIEFF

IT has long been known that the presence of certain substances *(promotors)* in a given catalyst increases its activity. But to explain how they influence a catalyst in a given reaction presents innumerable difficulties. Unrelated facts, generally observed by accident, have trickled drop by drop into the body of this science to form the mass of data on which various people have based various explanations of this phenomenon. Most of these have been inspired by the physical changes which take place. Because the rate of chemical reaction depends on the area of the surface of the catalyst, scientists saw in the promotors a means of increasing the surface of the catalyst, and thereby either increasing the amount of active center or preventing the growth of crystals in the catalyst. No one paid much attention to the possibility of the promotors taking part with the catalyst in the rate of reaction because it was not established that the catalyst itself can produce a definite chemical reaction with a catalyzed substance under suitable conditions (namely such reactions as would agree with its chemical function). So, in order that one could see "chemism" in catalytic chemical reactions, and with its help, try to understand them, it was necessary to discover a series of new reactions and their corresponding catalysts. Then by comparing the chemical properties of the catalyst and the substance on which it is to work, we can begin to understand the chemical reaction which will take place. This new knowledge will allow us soon to classify catalysts according to their catalytic actions based on their chemical properties. The last 40 years have already given us such a wealth of experimental data on chemical reactions that even now we are able to make certain predictions on the choice of a catalyst for a given reaction.

In many reactions studied we found that the catalyst forms intermediate compounds which fully explain the mechanism of the catalytic reactions. For example, polymerization of propene with phosphoric acid goes through the formation of isopropyl-phosphate. Intermediate compound formation also occurs with other catalysts such as hydrogen halides, sulfuric acid, perchloric acid, etc. The same is true for the isomerization reaction of olefins involving the shifting of hydrogen, as shown in my work with Pines and Schaad.[1]

In many cases the role of a promotor can be explained only on a chemical basis. The case of aluminum chloride-hydrogen chloride may be cited.

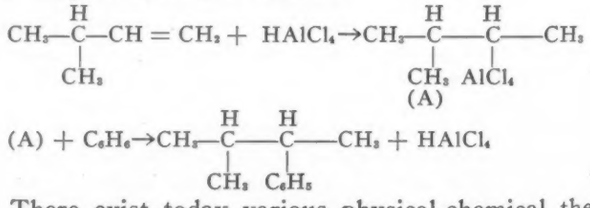
Pure aluminum chloride is not a catalyst for alkylation unless hydrogen chloride is present, either added as such or formed in situ. Working with Drs. Pines and Schmerling,[2] I have shown that this is due to the fact that the hydrogen chloride is necessary for the formation of hydrogen aluminum tetrachloride which is the true catalyst for the reaction.

IN accepting the Willard Gibbs medal for 1940 Vladimer N. Ipatieff reviewed the progress of catalysis under the title, "Mixed Catalysts," a subject that has demanded much of his investigations over 40 years. He is the inventor of the U. O. P. Polymerization process. In addition to his duties as director of research for Universal Oil Products Company he is professor of chemistry at Northwestern University.

The paper is typical of the pure scientist in that it pays tribute to accidental accomplishments as well as deliberate experiments, both of which come only to the point of leaving science with much more to learn.

The Willard Gibbs medal is awarded annually by the Chicago Section of the American Chemical Society and is one of many honors to come to the author of more than 200 scientific articles and monographs and the holder of more than 50 United States patents. Other honors include: correspondent member, Academy of Sciences, Goettingen, Germany; doctor honoris, University of Munich; honorary member of Deutsche Chemische Gesellschaft; doctor honoris, University of Strasbourg, France; commander, Legion of Honor, France; Berthelot medalist, France; member, National Academy of Sciences of the United States.

Thus the alkylation of benzene with isopropylethylene may be written as follows:



There exist today various physical-chemical theories which try to explain catalytic processes by the aid of the electron theory, ion theory and others. I do not dispute the benefits to be derived from such investigations, but it is my contention that we chemists must first investigate the chemical properties of catalysts, both simple and mixed, in order to understand the processes occurring from the chemical point of view. This was the purpose of our last work, and I want to tell you about some of the more interesting results obtained by us.

The significance of the influence of the mixed catalyst nickel-oxide and alumina which I discovered in 1910-12[3] on the rate of catalytic hydrogenation opened a new page in the field of catalysis.

Alumina, introduced into the reaction, for example, the synthesis of camphane from camphor, could not be called a promotor because it was 30 percent of the composition of the catalyst; and the experiment

showed that its presence stipulated a special reaction—dehydration, because of its chemical properties.

The role of alumina may be shown by the following equation:

$$2AlO(OH) + 3NiO \rightarrow Al_2O_3 + H_2O + Ni$$
$$Ni + H_2O \rightarrow NiO + 2H$$
$$2H + C_nH_{2n} \rightarrow C_nH_{2n+2}$$

Alumina helps the conversion of NiO to active metallic nickel, which converts in turn the water formed on its surface to atomic hydrogen.

The recent work by Polanyi with heavy water confirms this supposition.

Gain in Energy

For the first time we showed that when two catalysts are together they can produce separate reactions, thereby giving one or more products, depending on the chemical properties of the catalyzed substance. This experiment also helps us see how one reaction helps another by the utilization of the energy developed by the process. We must not forget that by using a catalyst for a reaction we always have a gain of energy, this gain coming from the transformation of different kinds of external energy into chemical. In catalytic reactions we observe two kinds of transformations of energy; first, that which is produced by transforming applied energy such as heat into chemical.

An example is the action of the catalyst alumina which is able to take water from alcohols. The molecules of alumina, receiving definite amounts of chemical energy, will be able to split the molecules of alcohol in a definite direction, taking water from them. The water will momentarily join with alumina, but as it cannot be held at the temperature at which the reaction is going, it will leave the sphere of reaction, and the process will begin again. A second kind of energy transformation is that which is born in the sphere of the catalytic process. An example is inter-molecular hydrogenation (disproportion of hydrogen) which Dr. Pines[4] and I observed in different kinds of catalytic reactions; conjunct polymerization, cleavage of aromatics compounds, etc. If the heat energy separated by one process transforms itself into a chemical energy which possesses a sufficient factor of tension, it will produce another reaction. Now after the discovery of the common action of catalysts we are able to understand processes to which, before, we were not able to give a suitable chemical explanation. The mixed catalyst nickel-oxide and alumina helps the hydrogenation of camphor, fenchone, and other saturated cyclic ketones because alumina dehydrates the intermediate alcohols into unsaturated hydrocarbons which are much easier to hydrogenate than the original ketones.

The study of the common action of mixed catalysts permits us to understand better the action of promotors. What is the difference between the terms promotors and mixed catalysts? I think that it is impossible to show any distinction between them. Just as one, so the other can serve two purposes: either improve the physical conditions of a catalyst, or evoke a new reaction which will help the other. Everything depends on the properties of the components of the mixed catalyst and the catalyzed substance. The investigations made by Drs. Corson, Kurbatov and myself[5] showed that sometimes it is necessary to add only a very small amount of one catalyst to another of the same type to greatly increase the activity of the latter. We made a number of systematic experiments with mixed catalysts containing reduced copper and different oxides, mostly chrome oxide, studying the hydrogenation of benzene and isopentene under ordinary pressure and 225° C.

TABLE 1
Hydrogenation of Benzene over Copper-Chromium Oxide Catalysts

Cr_2O_3 Weight, Percent	*Cr_2O_3/Cu Percent	†Hydrogenation of Benzene, Wt., Percent
0	0	0
0.1	0.0004	3
0.5	0.002	13
1.0	0.004	13
5	0.02	16
10	0.05	14
25	0.1	8
50	0.4	4
75	1.3	2
90	3.7	1
99	41.0	0
100	.....	0

* Ratio: Moles of chromium oxide/atom of copper
† Conditions: T., 225° C.; C. T., 90 sec.; H_2/C_6H_6, 7; press., atmos.

Under the test conditions, both of the pure components—copper and chromium oxide—were inactive, but as chromium oxide was added to copper, the activity rose abruptly to a maximum at 5 percent of oxide, and then fell with continued addition. Incidentally, catalytic activity in these copper-chromium oxide catalysts was accompanied by pyrophoricity, although there is no simple relationship between these two characteristics.

We propose to call this composition of maximum activity the *eucoactic* composition. It will be interesting in the future to study the dependence of the eucoactic composition upon the type of unsaturation and upon the operating conditions. Another problem for future study concerns poisoning and heat of deactivation as a function of chemical composition.

Adkins[6] and Calingaert and Edgar[6a] have previously described a number of copper-chromium oxide catalysts, with and without calcium, barium, strontium, and magnesium as stabilizers, but they used high pressure and a much higher concentration of chromium oxide than would be recommended on the basis of this work.

Results in Hydrogenation

The data in Table 1 show that the most active hydrogenating catalyst of the copper-chromium oxide series, for the experimental conditions used, contains 95 percent copper and 5 percent chromium oxide.

The subject becomes more complicated when we add a third substance, nickel, to this mixed catalyst. Our former experiments had established that nickel, with the carrier Kieselguhr (70% Ni: 30% Si), can completely hydrogenate benzene at 50° C. and one second contact time at ordinary pressure, and that

TABLE 2
Promoting Effect of Nickel on Copper and Copper-Chromium Oxide Catalysts

Cr_2O_3 Weight Percent	Nickel Wt., Percent	*Hydrogenation of Benzene, Wt., Percent	Contact Time Seconds
0	0.001	0	90
0	0.005	4	90
5	0.000	16	90
5	0.001	16	90
5	0.005	24	90
0	0.2	19	12
5	0.001	2	12
5	0.2	62	12

* Conditions: T., 225° C.; H_2/C_6H_6, 7; pressure, atmospheric.

neither copper nor chrome-oxide, the components of the mixed catalyst, is able to produce this reaction even slightly. When copper and chrome-oxide are mixed in proportions of 95 percent copper and 5 percent chrome-oxide (eucoactic at 225° C.) this mixed catalyst will hydrogenate benzene 16 percent in 90 seconds contact time. The Table 2 shows the interesting results obtained by the addition of nickel to copper and copper-chromium oxide catalysts (eucoactic composition) as measured by their ability to hydrogenate benzene.

Mixed copper-chromium oxide catalysts are even more susceptible to activation by traces of nickel than copper alone. For instance, copper containing not more than 0.001 percent of nickel does not hydrogenate benzene at ordinary pressure and 225° in 90 seconds, and the presence of 0.005 percent of nickel raises the hydrogenation to 4 percent. On the other hand, the hydrogenating activity of the 95 percent copper-5 percent chromium oxide is raised from 16 percent to 24 percent by the addition of 0.005 percent of nickel.

Another example of this amplifying effect is the following. The addition of 0.2 percent of nickel raises the hydrogenating activity of copper from 0 to 19 (percent hydrogenation of benzene at ordinary pressure and 225° C. in a contact time of 12 seconds), whereas the same addition of nickel raises the activity of the 95 percent copper-5 percent chromium oxide catalyst from 2 to 62.

The same kind of results were obtained in the hydrogenation of tri-methyl-ethylene using 0.003 percent of nickel with the copper-chromium oxide catalyst, as shown in the Table 3.

TABLE 3
Hydrogenation of Isopentene Over Copper-Chromium Oxide Catalysts

Cr_2O_3, Weight, Percent	*Hydrogenation of Isopentene, Wt., Percent
0	0
0.05	46
0.1	51
1.0	79
2.5	96
25	85
50	66
75	40
100	0

* Conditions: T., 75° C.; C. T., 10 sec. H_2/C_5H_{10}; pressure, atmospheric.

Pure copper (nickel, about 0.001 percent) does not hydrogenate isopentene at ordinary pressure in 10 seconds at 75°, but it does so to the extent of 6 percent in 14 seconds at 100° C., and 85 percent in 20 seconds at 225° C. Under 125 atmospheres of hydrogen at 100° C., hydrogenation is complete.

Effect of Chromium Oxide

The effect of small amounts of chromium oxide is remarkable. Copper requires 225° to hydrogenate isopentene 55 percent in 10 seconds, whereas copper containing 0.1 percent of chromium oxide shows the same activity at 75°. Thus, the presence of 1 mole of chromium oxide in 2500 atoms of copper lowers the temperature requirement 150°, although chromium oxide alone has no hydrogenating ability, even at 350° under 150 atmospheres of hydrogen.

Dr. Corson and I[7] also studied the performance of 14 series of mixed copper catalysts containing different metal oxides. These catalysts were carefully made from reagent chemicals and several compositions in each series were determined by analysis. Evidently there are many substances which, although catalytically inactive alone, possess the property of activating copper for the hydrogenation of benzene.

We further determined the eucoactic composition in all these mixed catalysts, and we noticed that in some cases the maximum activity remains constant over a certain period even though the percent of metal oxide was increased. In other cases, although at first a small addition of the promotor gave a sharp increase in the activity of the copper, the eucoactic point was reached only after very much larger additions of the metal oxide, after which the activity fell sharply to zero.

What conclusions can we draw from these experiments with mixed catalysts? Our experimental data shows that one of the most important is that in studying catalytic reactions from a physical-chemical point of view, it is necessary to pay special attention to the purity of the catalyst. Until now, little attention has been given to this, and if analyses of catalysts were made, methods were used which have a high percentage of experimental error. Such analyses are of little use in the study of the activity of a catalyst.

Role of Copper

In our former work we showed that Pease and Purdum,[8] limited by some such chemical analyses (unfortunately, they did not tell which method they used) which showed them that their copper did not contain Ni or Cobalt, came to the erroneous conclusion in their experiments that pure copper can be a hydrogenating catalyst for benzene. Our experiments have shown that the commercial copper-oxide from Merck & Kahlbaum, which Pease and Purdum used to reduce by their method to copper, contained .1 percent nickel, or, in other words, such an amount which when added to pure copper will then permit it to hydrogenate benzene 40 percent under the conditions used by them. Pure copper, containing 0.001 percent nickel as determined by spectro-analyses, is not able to hydrogenate benzene at all under the conditions of 225° and ordinary pressure and a great contact time. From this point of view Sabatier and Sanders were right when they confirmed that pure reduced copper is not a catalyst for the hydrogenation of benzene, although they also failed to give their method for analyzing the copper or the conditions under which is was obtained. It is possible that under these conditions the copper catalyst lost its activity. However, we discovered that if benzene is hydrogenated under pressure, then both pure reduced copper and copper oxide will catalyze the reaction.

Our calculations show that when copper contains 0.001 percent nickel, one atom of nickel is surrounded by 90,000 atoms of copper, and benzene cannot be hydrogenated under ordinary pressure. If we increase the nickel content to 0.002 percent, where one atom of nickel is surrounded by 45,000 atoms of copper, we can detect a slight addition of hydrogen to benzene. With the nickel content 0.02 percent, the proportion of copper to nickel atoms being 4,500 to 1, benzene is hydrogenated 2.5 percent. In the same contact time, if nickel is increased to .1 percent, corresponding to 900 atoms of copper to one of nickel, the hydrogenation of benzene reaches 10 percent.

We cannot explain the great increase in the activ-

ity of the copper when nickel is added as being due only to the presence of a strong hydrogenating catalyst because we get entirely different results when nickel is precipitated with alumina. Our experiments showed that 5 percent nickel on precipitated alumina could not hydrogenate benzene at all under 225° and 180 seconds contact time, and it was only with 10 percent nickel that benzene was hydrogenated 92 percent in 23 seconds contact time. These parallel experiments with different nickel carriers force us to the conclusion that when a mixed catalyst consists of two metals we have the appearance of a new energy which helps the process, and it is our assumption that these two metals act as thermo-couples and produce a form of electric energy. We showed that nickel activates copper still more when 5 percent chromium-oxide is added (giving the eucoactic point for copper-chromium-oxide); here we can also assume the appearance of electrical energy due to the presence of two metals, but we must leave for the future to explain what influence the oxides of metals have upon the activity of mixed catalysts.

In our experiments on the hydrogenation of benzene in the presence of reduced copper, we used Dr. Hahn's method of emanation for the study of the dependence of the activity of a catalyst on its surface area. The data without doubt are very interesting, but we consider them only as preliminary experiments, and can draw from them only limited conclusions. It was established that the addition of alumina or chromium-oxide to copper brought about a considerable increase in emanating ability, and, therefore, a considerable increase in surface. Our experiments have shown that the activity of such a mixed catalyst grows very rapidly as additions of the oxide are made, reaching maximum activity at a definite percentage content of the components of the catalyst. We know that the speed of catalytic reactions depends on the surface area and that the larger the surface area, the more active the catalyst. We must acknowledge that our present knowledge does seem to point out that new substances introduced into the catalyst play a passive role, serving only to improve the physical properties of the catalyst, such as its surface, but we believe that metal oxides introduced into the catalyst possibly do fulfill some chemical function thereby activating it. Such assumptions can be answered only by further systematic experimentation, and the emanation method, I believe, will be of great help in explaining the many complicated events which take place.

Water in Catalytic Reactions

Another thing to which we must pay more attention in the future is the influence of water on catalysts. We find many contradictory results on this point in chemical literature, and I think one reason this question has not been elucidated before is because little attention has been paid to the purity of the catalyst, and therefore accurate determination of the kind of influence water exerted could not be made. In my opinion, water plays a very important part, but we must determine separately the influence of various amounts of it in any given reaction. According to the hypothesis which I made 40 years ago, catalytic processes of reduction and oxidation occur only when water takes part in the reaction, and therefore metal oxides heated to such a temperature that they do not hold any hydrate cease to be catalysts. Also in the catalytic dehydration of alcohols in the presence of alumina the latter must contain a definite amount of water so that the reaction may go under lower temperatures, and give almost the theoretical yield in olefins. We find a very good confirmation of my hypothesis concerning the role of metal oxides and water in the synthesis of hydrocarbons from carbon-monoxide and hydrogen by the method of Fisher and Tropsch in the presence of the mixed catalyst cobalt oxide and thorium oxide—hydrogenation and dehydration catalysts. Experiments have shown that the best catalyst for this process is one wherein 70 percent of the cobalt oxide is reduced to metallic cobalt and therefore allows the catalyst to retain a considerable amount of both cobalt oxide and water.

In catalytic process it is very important that the substances taking part in the reaction should appear in nascent state whereby they, possessing a sufficient amount of energy, will be able to react with each other, this being impossible if they are in an ordinary state. In order that a catalytic process would go like any other chemical process it is necessary that the energy given out be able to prepare the neighboring molecules to go into the reaction and that this repeat itself indefinitely; then the catalyst will fulfill the role of *multi-actor*. The activating energy of a catalyst can be very great, but it will not be able to work if conditions will not be suitable for its action.

On the other hand, a catalyst with not much activating energy will be able to produce a desired reaction if the external energy be transformed into chemical energy which has a sufficient factor of tension. It is also necessary that this energy does not disperse but is handed on to the neighboring molecules with a sufficient factor of tension so that the reaction will continue. An interesting example of this is an experiment made by Dr. Corson and myself wherein we hydrogenated benzene under pressure in my bomb, using reduced copper as catalyst. We found that if we used a small amount of the catalyst, the benzene would not hydrogenate at all, despite a long contact time; it was necessary only to increase the catalyst to a certain amount to hydrogenate benzene completely.

On the other hand, if the released energy will have too large a factor of tension, the process, going at such a great speed, will soon stop altogether. The energy released by the reaction will be so great as to de-activate the catalyst; its physical properties will be changed and its surface diminished, leaving the catalyst unable to continue the reaction. In short, the catalyst will cease to breathe.

All these events we have observed in many experiments in hydrogenating different unsaturated hydrocarbons, and especially those who have studied these processes on a large scale know how careful it is necessary to be with catalysts. Especially at the beginning it is necessary to pay attention to the catalyst, the so-called "incubation" period until the catalyst comes into its strength, as only with careful handling will it possess a long life and give the desired results.

The Poisons of Catalysts

Chemical literature contains many articles concerning the deactivation of catalysts from which we can draw one indisputable conclusion. The amount of a substance which can poison a catalyst can be so small

that a molecular film will not cover the catalyst completely. A hypothesis was made on the basis of this data that only the active centers of the catalyst are poisoned, and this explanation, in turn, was used to confirm the existence of such centers in the catalyst. I do not intend here to criticize this hypothesis, nor the necessity of introducing such a term for the explanation of catalytic reactions, but I, nevertheless, believe that molecules of different chemical constitution will always be found in a catalyst. If the catalyst is a reduced metal, it will also contain the metal oxides (as shown by many analyses); if the catalyst contains metal oxides, then some of its molecules will be metal hydrate-oxides, etc. On the basis of my theory of catalytic processes, these molecules having a definite composition will serve as initiators of definite chemical reactions if the conditions will be suitable for this process. For example, only the presence of definite amounts of a particular hydrate of alumina oxide in an alumina catalyst will give this catalyst the ability to take water from alcohols with the theoretical yield at low temperatures. The same thing can be said about the presence of metal oxides in reduced metals and their hydrogenating activity.

A catalyst poisoner being introduced in negligible amounts can stop the action of a catalyst by weakening or paralyzing the action of the molecules producing a given process, in consequence of which the neighboring molecules will not receive a sufficient amount of energy and the process will choke. We can observe a similar event in poisoning in the animal kingdom. A minute amount of poison can kill a large animal, this happening because the physiological process in a very limited place of the organism is stopped: energy cannot be carried to other organs of the body, and a swift death results.

Permit me to mention some physiological experiments made by Prof. Babkin[9] concerning the poisoning of organic mixed catalysts—enzymes. I refer to this example to once more emphasize the uniformity of laws governing catalytic reaction in the animal and vegetable as well as in the mineral kingdom.

We know that digestion occurs in the stomach under the influence of enzymes or mixed catalysts—pepsin and hydrochloric acid. The percentage of hydrogen chloride in the hydrochloric acid is approximately 0.5. Such a weak acid cannot hydrolyze proteins, but with the help of pepsin it can change them into peptones; this reaction occurring very rapidly at body temperatures. In view of this, physiologists have long sought an answer to the question: why does this mixed catalyst not break down the walls of the stomach which consists mainly of proteins? Dr. Babkin gives one explanation. It has been found that the gastric glands secrete a special mucus which coats the lining of the stomach, and which, when dissolved in small amounts in the gastric juice, greatly weakens the peptinizing action of hydrochloric acid and pepsin. It was found that changing the concentration of the hydrochloric acid did not diminish the neutralizing action of the mucus, so that it is obvious that the pepsin alone was deactivated by the mucus. Dr. Babkin established that the inhibiting action of the mucus was due to certain acids in the mucus—mucoitin-sulphuric and chondroitin-sulphuric acids. The vagus nerve, which controls the secretion of the mucus, reacts when there is no food in the stomach and causes the mucus to be secreted, thus preventing the catalyst from working on the walls of the stomach. So we see that the introduction of a new substance into the sphere of reaction can greatly weaken the action of a mixed catalyst whether organic or inorganic.

We saw earlier that the addition of a minute amount of nickel to the mixed catalyst copper chromium-oxide greatly increased its activity. But this mixed catalyst can lose its activity in part or completely, if we add to it a small amount of other substances such as lead, cadmium, bismuth, certain salts, etc. Dr. Corson and I[7] studied the poisoning effect of several metals and salts on two mixed catalysts: copper-nickel and copper-chromium-oxide, under ordinary and high pressure. We took two catalysts for our study in order to show that a mixed catalyst activated by the addition of chromium-oxide is better able to resist the action of poisons.

We took the hydrogenation of benzene as the reaction for our study of the poisoning of catalysts. Table 4 shows our results using 99.8 percent copper and 0.2 percent nickel as the catalyst, and bismuth, cadmium and lead as poisons.

TABLE 4

Poisoning Effect of Bismuth, Cadmium and Lead on Copper and Nickel Catalysts

Poison Weight, Percent	Hydrogenation of Benzene Weight, Percent		
	Bismuth	Cadmium	Lead
0.0	19	19	19
0.00001	16	20	28
0.0001	15	20	27
0.001	17	18	24
0.01	10	13	16
0.1	3	3	2
0.2	0	0	0
1.0	0	0	0

Conditions: T., 225°; C. T., 12 sec.; H_2/C_6H_6, 7; pressure, atmospheric.

At ordinary pressure 0.1 - 0.2 percent of bismuth, cadmium or lead deactivates 99.8 percent copper and 0.2 percent nickel almost completely. Below 0.1 percent concentration, bismuth and cadmium have no effect, whereas lead functions as a weak promotor. This interesting behavior of lead was checked several times with different catalyst preparations so as to make sure of the facts. Lead, therefore, is similar to certain drugs which in small doses stimulate the living organism, but in larger doses cause death. In literature we can find a similar instance in catalysis which was observed by Chosh and Bakshi[10] who reported that 0.04 percent of carbon bisulfide and 0.14 percent of chloroform activated copper for the dehydrogenation of methyl alcohol by factors of 1.8 and 2.25 respectively, whereas 0.41 percent of either of these poisons completely deactivated the catalyst. The experiments with poisoned nickel-copper catalyst leaves a doubt whether the poison affects only the nickel or the copper or both.

An alternative method is to study the poisoning effect under more severe conditions of time, temperature, and pressure, choosing such conditions that pure copper shows sufficient activity to allow evalua-

TABLE 5
Catalyst Copper Poisoning by Bismuth, Cadmium and Lead

Poison Weight, Percent	Hydrogenation of Benzene		
	Bismuth	Cadmium	Lead
0.000	33	33	33
0.005	21	6	5
0.05	6	1	1
0.5	2	0	0
1.0	0	0	0

Conditions: T., 350°; reaction time: 12 hours; charge 50 cc. of benzene, 5 gr. catalyst, 100 atms. of hydrogen; apparatus: 850 cc. Ipatieff rotating bomb with glass liner.

tion of the poisoning effect. The results are shown in Table 5.

As may be observed, we obtained the same picture with poisoned copper at superatmospheric pressure as at ordinary pressure with poisoned 99.8 percent copper and 0.2 percent nickel.

Poisoning of Copper Chromium-oxide and Nickel

We previously reported that nickel is more effective in the activation of 95 percent copper 5 percent chromium-oxide than of pure copper. Table 6 shows the effect of lead on the activity of this catalyst.

TABLE 6
Poisoning of Copper-Chromium Oxide Nickel by Lead

	Hydrogenation of Benzene Weight, Percent
Copper	0
Copper—5% Cr_2O_3	2
Copper—5% Cr_2O_3-0.2% Ni	62
Copper—5% Cr_2O_3-0.2% Ni-0.1% Pb	23

Conditions: T., 225°; C. T., 12 sec.; H_2/C_6H_6, 7; pressure, atmospheric.

A comparison of the data of tables 4 and 6 shows us that 0.1 percent of lead lowers the activity of the nickel promoted 95 percent copper 5 percent chromium-oxide from 62 to 23 (63 percent drop) and that of nickel promoted copper from 19 percent to 2 percent (90 percent drop).

As a result of these investigations with mixed catalysts containing activating and poisoning substances, we can make the following remarks. Our preliminary survey emphasizes the extreme delicacy of catalytic processes and the necessity of careful definition of purity before drawing conclusions as to the catalytic properties of any particular element of catalyst. The sensitivity of the system benzene-hydrogen-copper competes with the spectroscope in the detection of traces of nickel, bismuth and cadmium, and it goes beyond the range of the spectroscope in its sensitivity to traces of lead. Therefore in the case of lead, at least, spectroscopic purity is no guarantee of catalytic purity, which means that in order to introduce into the catalyst traces of different promotors or poisons, it is necessary to prepare the catalyst by a special method to be sure of its composition.

In conclusion, I wish to state that for a thorough investigation of the mechanism of catalytic reaction it will be necessary to apply all the chemical and physical tools at our disposal.

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Elements of Vaporization and Condensation

PART VI
Pressure Temperature Composition Relationships of Binary Mixtures

By R. L. HUNTINGTON, University of Oklahoma

A SOUND understanding of the principles underlying the behavior of various binary mixtures is essential for the engineer who expects to become proficient in the design of fractionation and distillation equipment. In the several previous papers of this series[1] some of the elementary laws have been explained, as well as specific examples showing the application of these laws to field and plant practice.

In general, there are three types of binary mixtures to be considered, (1) mixtures in which the two components are miscible in all proportions, (2) mixtures in which the two components are totally immiscible, i. e. there is substantially no tendency for the one to mix or form a solution with the other, (3) mixtures which are miscible within certain ranges of composition but outside of these ranges form two phases, each phase being a definite mixture of the two components.

Miscible Mixtures

Pressure Composition Diagram—When two components are miscible in all proportions in the liquid phase, there is a tendency for the one having a higher vapor pressure to speed up the other which has a lower vapor pressure, and vice versa. Such a behavior might be compared to a team of horses, where a spirited horse might have a tendency to speed up the slower-moving member of the team. And likewise the slower member would tend to reduce the speed of the faster horse. When two liquid components behave in such a manner as described above, it is said that they perform according to Raoult's law.

Figure 1 is presented in order to picture this performance in terms of the partial pressures exerted by each compound in the liquid state. Referring to this diagram, it is seen that the partial pressure of butane varies from zero when all of the liquid consists of pentane, while

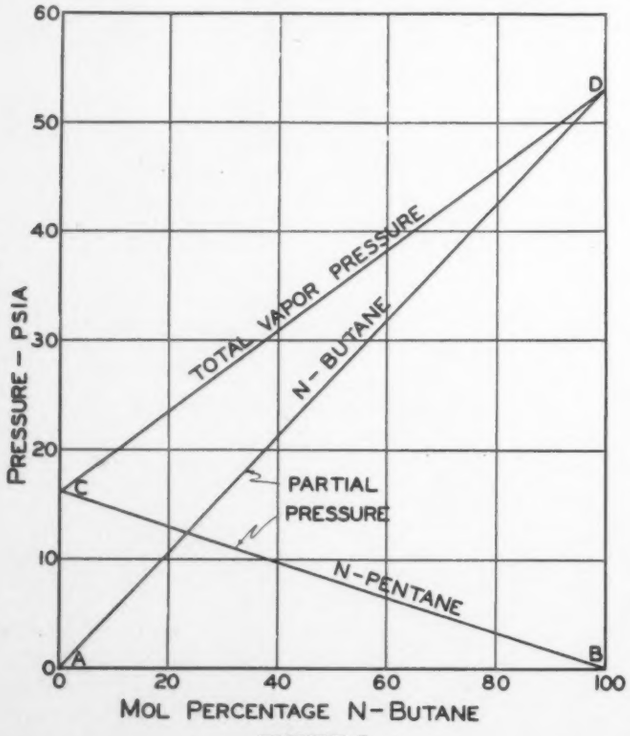

FIGURE 1

Graph showing relationship of partial pressures to mol fractions for normal butane-normal pentane mixtures. Temperature=100° F.

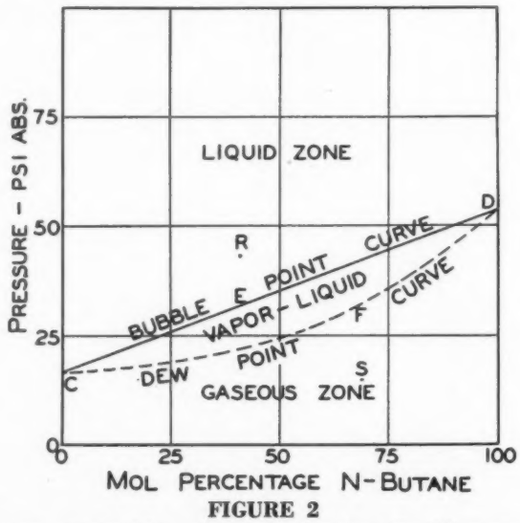

FIGURE 2

Pressure composition diagram showing liquid gases and vapor liquid regions for normal butane-normal pentane mixtures at 100° F.

its partial pressure is 53 pounds per square inch at 100° F. when all the liquid is normal butane. The partial pressure of the butane in intermediate mixtures is shown by line AD. Likewise, the line BC shows the partial pressures of the pentane between zero percentage up to 100 mol % pentane. The sum of the partial pressures is shown by line CD. In other words, a 50-50 mixture of the two components will exert a total vapor pressure half way between C and D, or $\frac{16+53}{2}$ which is equal to 34.5 pounds per square inch absolute. It is well to remember that this chart is based on one temperature which in this case is 100° F.

Another way of presenting the pressure-composition

relationship is shown in Figure 2 in which the three regions, gaseous, vapor-liquid, and liquid zones are shown. The line CED represents the boundary between liquid and the liquid-vapor zones. Or in other words, points along this line are called bubble points. The dotted line CFD is the boundary between the gaseous and the vapor-liquid regions. This line is known as the dew point curve. If the pressure on a liquid at point R is lowered to location E, vaporization will occur, the first bubble of vapor being that of composition F horizontally opposite point E. If the pressure on the liquid is lowered still further, vaporization will continue to occur until all of the liquid is brought to point C, where total vaporization will have taken place. At the intervening points between E and C, the vapor composition in equilibrium with the liquid will fall on line FC at corresponding horizontal positions.

In the same way, if vapor at S is raised in pressure to location F condensation will begin to take place, the first drop of liquid being of Composition E. With further increase in pressure, the vapor will continue to condense, giving off liquid at points on line ED directly opposite the horizontal points on line FD.

Temperature-Composition Diagram

The relationship between the temperature and composition is shown in Figure 3 for a binary mixture of two miscible compounds. The envelope CD represents the enclosure of the liquid-vapor region while the area

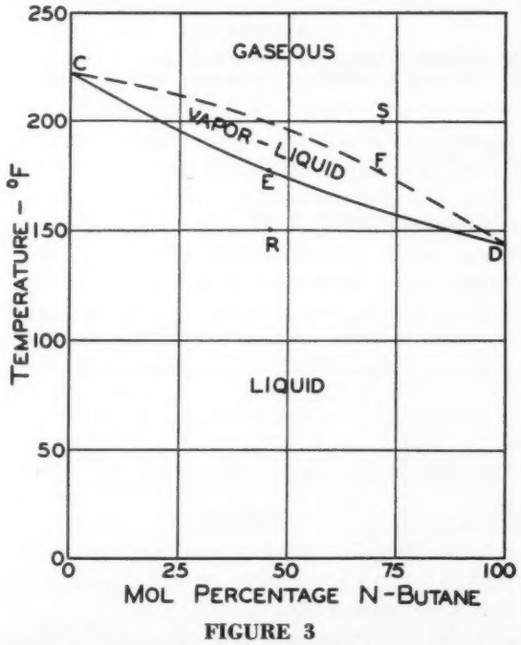

FIGURE 3

Temperature composition diagram for normal butane-normal pentane mixtures at 100 pounds per square inch absolute.

above is the gaseous region, and the area below, the region in which nothing but liquid can exist. This particular diagram has been made up for butane-pentane mixtures, all at 100 pounds per square inch absolute. The point C indicates that a temperature of 220° F. is necessary for normal pentane to exert 100 pounds per square inch, while normal butane will exert the same pressure at 144° F. The line CED illustrates the bubble points of various mixtures between the two extremes of 100 percent pentane and 100 percent butane. The dotted line CFD shows the dew points for the same range of mixtures. If we take a mixture consisting of 71.2 percent butane as indicated by point S, and cool this mixture at a constant pressure of 100 pounds from a temperature of 200° F., condensation will start at the point F at a temperature of 175° F. The liquid which will first condense out of this mixture will not be pure butane; however, it will be richer in pentane than the original vapor. In this case the composition of the liquid will be represented by the point E on the bubble point line horizontally opposite point F. This composition happens to be 48.5 percent butane. If cooling is continued, the vapor composition will fall down the dotted dew point line to D. Condensation of liquid richer in pentane is shown by points horizontally opposite the dew point on the bubble point curve. In a similar manner, a liquid at point R at a temperature of 150° F. when heated to a higher temperature, will begin to vaporize at point E at a temperature of 175° F.

The composition of the liquid and also the vapor at points E and F was determined by setting the temperature at 175° F. (Pressure already set at 100 pounds.) From the phase rule, the system is fixed. Applying Raoult's law:

$$\pi y = p x \qquad x_4 + x_5 = 1$$
$$C_4\ 100\ y_4 = 150\ x_4 \qquad y_4 + y_5 = 1$$
$$C_5\ 100\ y_5 = 53\ x_5$$
$$y_4 = 71.2$$
$$x_4 = 48.5$$

Immiscible Liquids

1. *Normal pentane-water system*—Although the hydrocarbons and water are slightly soluble in each other, they are generally considered to be immiscible from a practical standpoint. In such cases each liquid component can exert its full vapor pressure independent of the other. In Figure 4 a pressure-mol composition diagram

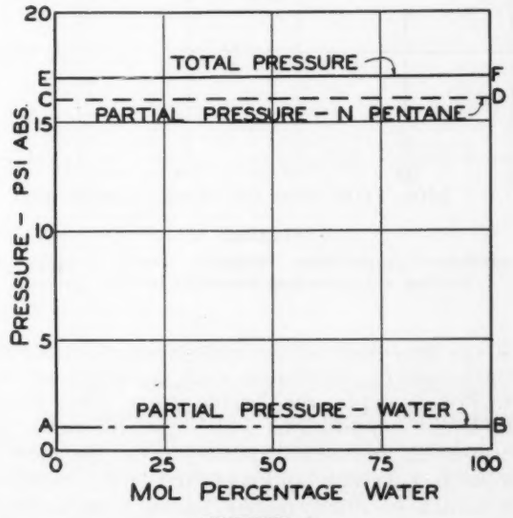

FIGURE 4

Partial pressure diagram for system of water and normal pentane.

is shown for a system containing mixtures of normal pentane and water at a temperature of 100° F. The partial pressure of water is represented by line AB (0.95 pound per square inch absolute) and that of normal pentane by CD (16 pounds per square inch absolute). The total pressure line is EF (16.95 pounds pressure). From this diagram it is easily seen that the total vapor pressure is the sum of the two vapor pressures, regardless of the percentage of each constituent present in the

liquid phase. The equilibrium vapor above any liquid mixture of normal pentane and water at 100° F. would be

$$\frac{16}{16.95} \times 100 = 94.3 \text{ mol \% normal pentane}$$

$$\text{and } \frac{.95}{16.95} \times 100 = 5.70 \text{ mol \% water vapor}$$

2. *Maximum and Minimum Boiling Point Mixtures*—There are certain aqueous solutions which possess the peculiar property of boiling at a constant temperature and pressure, provided a definite percentage of each component is present. No doubt some hydrate or loose physico-chemical union is formed between the water and the solute.

Water and hydrochloric acid are miscible in all proportions; however, they do not behave like a mixture of hydrocarbons, in that a maximum boiling point is reached whenever a definite percentage of water is present in the solution. Figure 5 is a representative

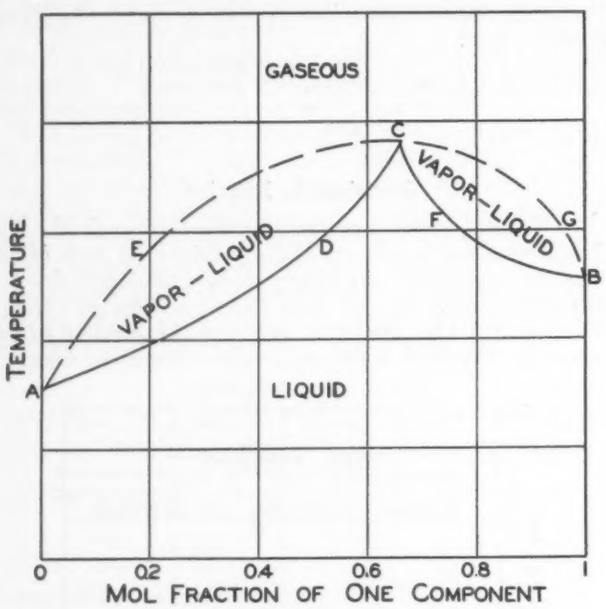

FIGURE 5
Temperature-Composition Diagram for a binary system having a maximum constant boiling point.

graph of the temperature-composition relationship for a binary system possessing such a maximum boiling point. For example, the bubble point curve ADC includes liquid compositions which give off vapor having corresponding horizontal positions on the dew point curve AEC. Likewise liquids at their bubble points along CFB would produce vapors having compositions on CGB. With rising temperature any liquid mixture would tend to approach the point C where the liquid and the vapor would be of the same composition.

Ethanol and water which are miscible in all proportions, form a minimum boiling point as shown in Figure 6. The bubble point curve is designated by CFDGE, while the dew point curves follow the dotted line CHDJE.

3. *Binary Systems of Partial Miscibility*—There are a number of binary systems in which the two components are miscible in each other over certain narrow ranges of composition. Outside of these two ranges the two components form two phases, each phase containing a certain percentage of one constituent dissolved in the other. For example the system (aniline and water) behaves according to this rule. A pressure-composition diagram of this system is shown in Figure 7 at a temperature of 99° C. At this temperature water saturated with ani-

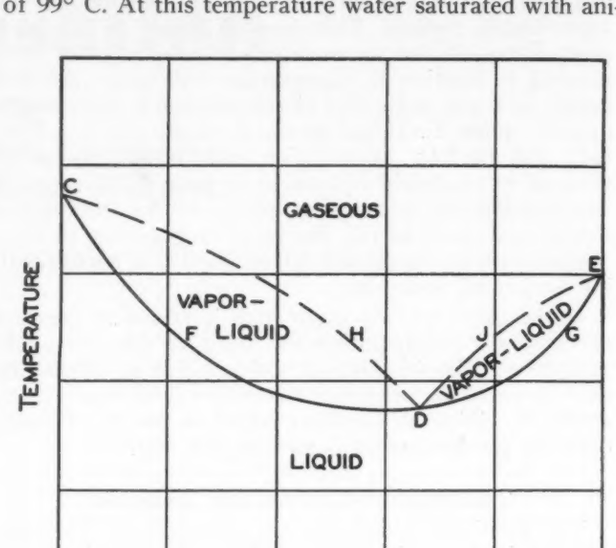

FIGURE 6
Temperature-Composition Diagram for a binary system having a minimum constant boiling point.

line contains 1.42 mol % aniline, while aniline saturated with water contains 31.6 mol % water and 68.4% aniline. Any mixture containing aniline between 1.42 mol % and 68.4 mol % will form two liquid phases, one, the water phase saturated with aniline, and the other, the aniline phase saturated with water.

From the diagram, it is readily seen that Raoult's law

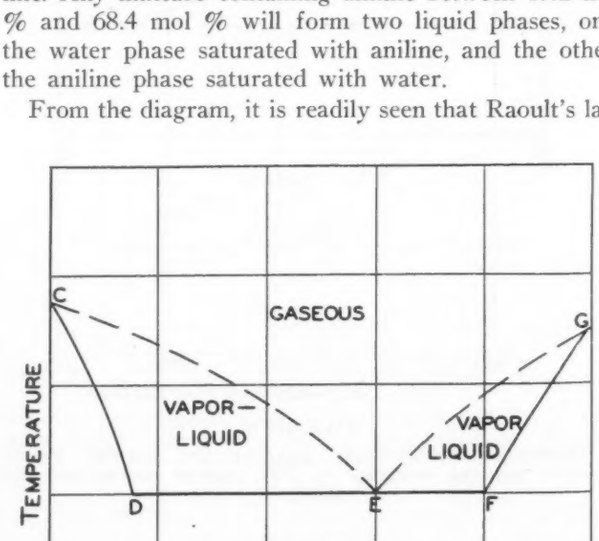

FIGURE 8
Temperature-Composition Diagram for a binary system of partial miscibility.

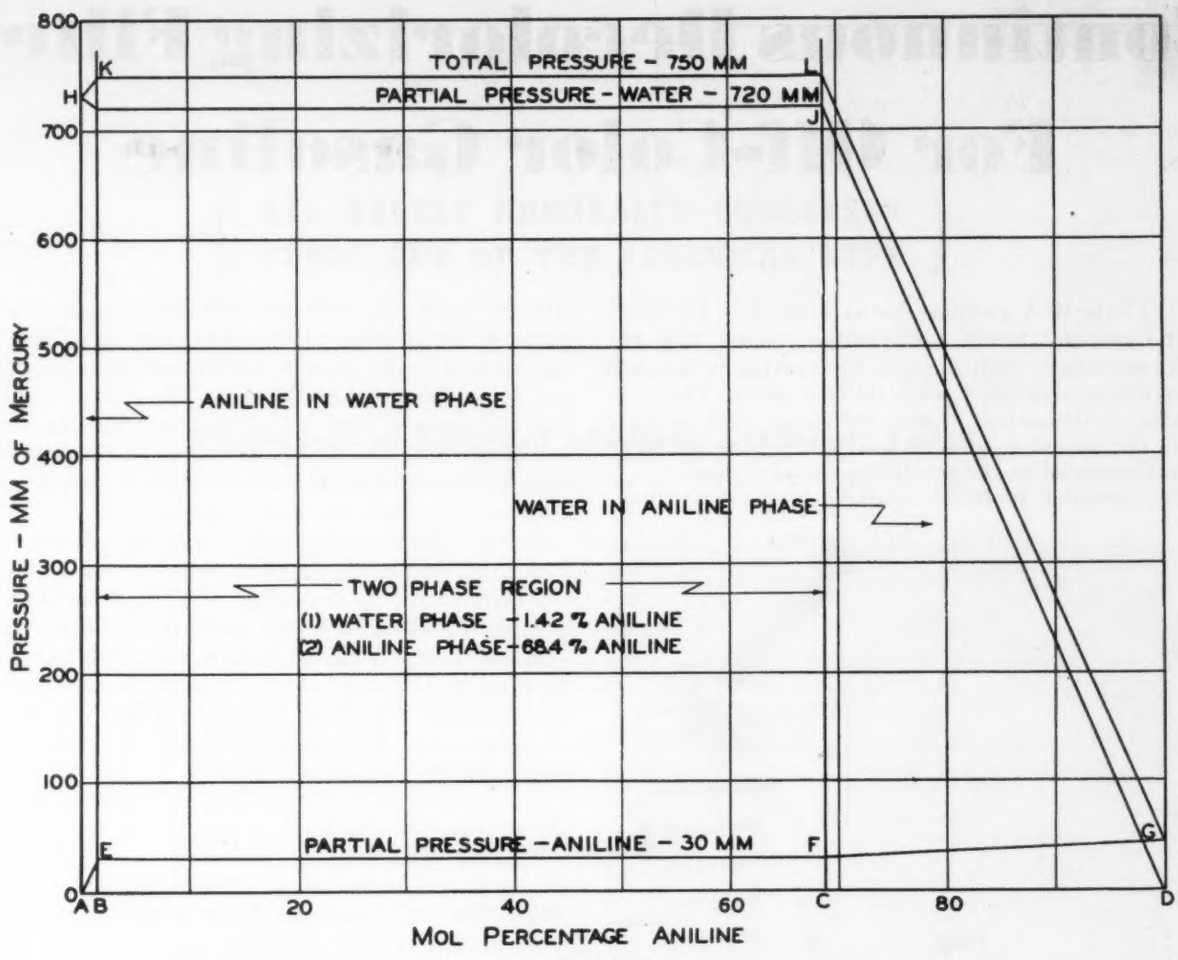

FIGURE 7
Pressure composition diagram for aniline water system at 99° C.

is the governing factor in the behavior of aniline in the aniline phase, and for water in the water phase. When either constituent is present in a phase in small percentage, such as aniline in the water phase and water in the aniline phase, it is to be observed by lines AE and JD that the aniline and water behave respectively according to Henry's law, where Y is equal to KX (Y and X are the mol fractions in the vapor and liquid respectively), K being determined experimentally. In these two particular cases, the constituent when present in small percentage, exerts a much higher relative volatility than it does when present in large percentage. For example, at point E on the partial pressure line for aniline, the relative volatility of aniline compared with that of water is 2.87. While at F where the partial pressure of aniline is the same, the relative volatility of aniline to water is only .019.

In order to gain a better understanding of this diagram it might be well to calculate the composition of the vapor coming from the following liquid mixtures:

(1) A liquid mixture containing 1 mol percent aniline.
(2) A liquid mixture containing 85 mol percent aniline.
(3) A liquid mixture containing 50 mol percent aniline.
(4) A liquid mixture containing 20 mol percent aniline.

Solutions:

(1) Partial Pressure of aniline $= \frac{1}{1.42} \times 30 = 21.2$ m.m. (See Line AE)

(2) Total Pressure = 745 m.m. (Line HK)
$21.2/745 = .0284 \times 100 = 2.84\%$ aniline in vapor

(2) Partial Pressure of aniline = 37.3 m.m.
Total Pressure = 380 m.m. (Line LG)
$37.3/380 \times 100 = 9.83\%$ aniline in vapor

(3) Partial Pressure of aniline = 30 m.m.
Total Pressure = 750 m.m. (Line KL)
$30/750 \times 100 = 4.0\%$ aniline in vapor

(4) Same as part (3)

Temperature-Composition Diagram for a Binary System of Partial Miscibility

The relationship of vapor to liquid composition for different temperatures all at a constant pressure is shown in Figure 8. It is interesting to observe that any liquid between points D and F will give off vapor of composition E. Liquids along the bubble point line CD will give off vapors along CE at horizontal positions on the respective curves, and likewise liquids along FG will evolve equilibrium vapor leaner in the same component along the line EG.

In the next of this series, a discussion will be given of some of the simpler methods used in determining the number of theoretical trays required for the separation of binary mixtures of hydrocarbons.

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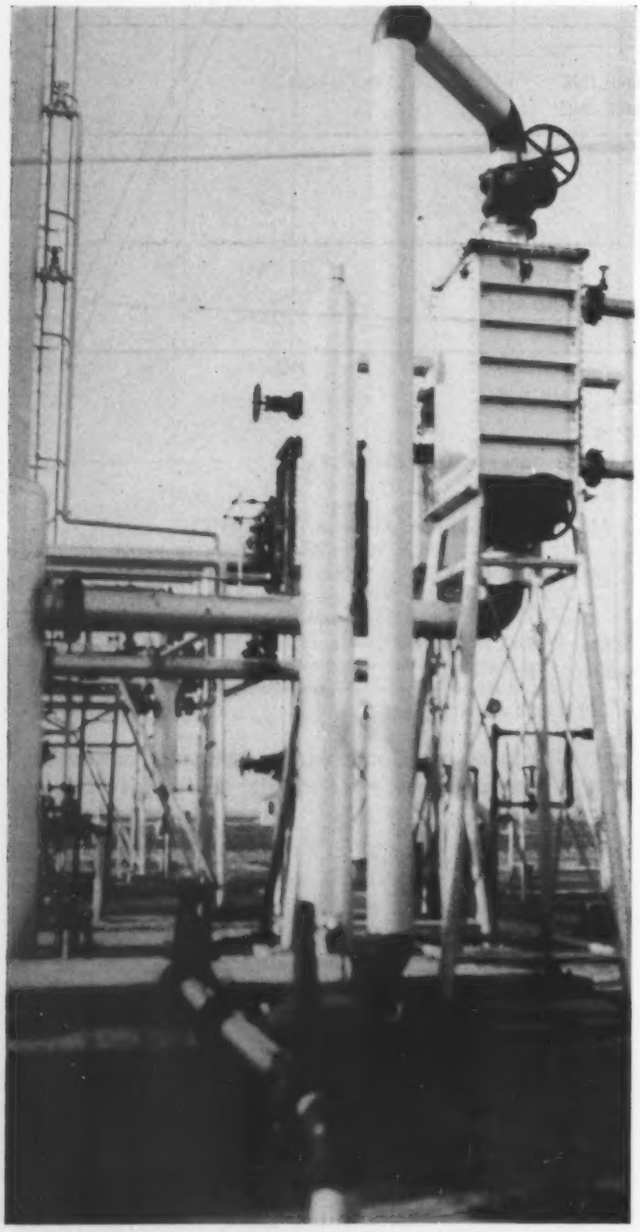
Continuous Decolorizing Filter For Off-Color Gasoline

IN ITS K-M-A gasoline plant Deep Oil Development Company treats condensate, coming into the intake scrubbers with the gas, by filtering it through a vertical vessel filled with fuller's earth. The condensate is deposited in the gathering system only when the weather is cold but the volume is large when compared to the production of the plant.

The off-color material consists of a small quantity of crude oil; not sufficient to increase the end point of distillation appreciably, but if passed into the stream of finished material sufficient to reduce the color value below 30 plus. The color is only in the condensate, and when the weather begins to warm up, the commodity recovered in the first stage of compresson is white and needs no treatment other than fractionating for vapor pressure.



Decolorizing filter used to clear up condensate brought into the scrubber with gas from wells.

For the decolorizing unit, a 10-foot section of 10-inch pipe was made up with heads at each end, the top terminating in a swedge of 10 to 6 inches. This is used for filling the pipe with fresh fuller's earth. The lower end is closed with a flat head, but a connection on the side at the bottom, consisting of a 6-inch nipple serves as an opening for the removal of spent clay. The column is placed near the intake scrubber and guyed vertical.

For the control of the flow of condensate from the scrubber to the filter, a connection was attached to the bottom gauge glass fitting on the tank, consisting of a ¼-inch collar, a 3-inch nipple and a needle valve. The top connection of the needle valve is fitted with a compression coupling for a ¼-inch copper tube, which leads from the needle valve to the top of the filter column. This connection was placed at the scrubber gauge glass fitting so the operator must always pass near enough to see the condition of the liquid level when attending to his duties.

The filter column is equipped with a ¼-inch outlet connection, consisting of a welded collar, nipples and a needle valve, with piping leading to storage tanks. The operation of the color filter is such that the column is maintained completely full of gasoline so long as condensate is produced in the intake scrubber. The needle valve on the filter outlet is pinched so the liquid level remains about half way up the first gauge glass, and, as the production of condensate is fairly uniform in cold weather, the setting requires little attention. The operator makes his rounds through the plant at frequent intervals, and is instructed to look closely at the level of condensate in the scrubber, and make adjustments when it either rises or lowers, as the case may be.

The column is relatively inexpensive and can be quickly made and attached to any plant with similar operating conditions in less than a day. During the past winter, only one filling of fuller's earth was required, and the condensate passed from the filter with a color of 30 plus. The product was either used for blending with fractionated gasoline to establish a definite vapor pressure commodity, or blended with heavier refinery material in the manufacture of motor fuel for company trucks and automobiles.

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Defense Plans Make Outlook Promising at Mid-Year

L. J. LOGAN

ALTHOUGH the war situation has brought about much uncertainty in the outlook for the United States' oil industry as well as most other lines, the industry has made a comparatively good record in the first half of 1940; and continued satisfactory results are promised by the national defense program, which is expected to cause an early stepping up of general domestic industrial and business activity.

The exceptional stimulation of domestic business by the preparedness campaign has potentialities for more than offsetting losses of export business brought about by the war. And for the oil industry this is particularly true. Even without benefit of extraordinary domestic activity, such as that contemplated for the next year or so, the oil industry of the United States so far in 1940 has encountered unprecedented demand for its products, despite sharply curtailed exports. With the domestic activity increased by the huge program of airplane manufacturing, shipbuilding, munitions accumulation, and general military expansion, the oil industry possibly will be handicapped even less in the latter half of the year by the dearth of foreign business.

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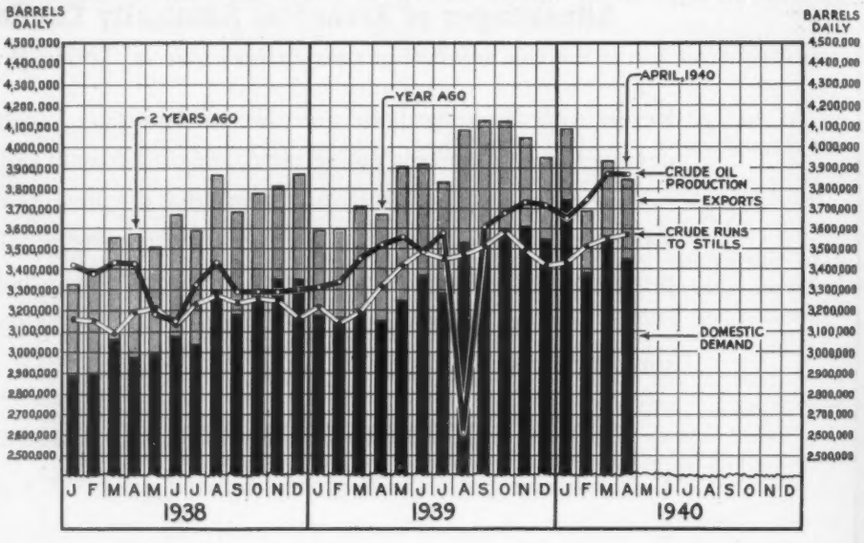


Nevertheless, the industry is operating under one serious disadvantage that will be a heavy burden even if business picks up materially. It is the large surplus of gasoline, which has depressed prices of that paramount product to levels among the lowest in the history of the industry.

Markets for other products of the industry have continued comparatively good, despite some weakening in the past several months, and a general business betterment doubtless would strengthen them and stabilize prices at current or higher levels.

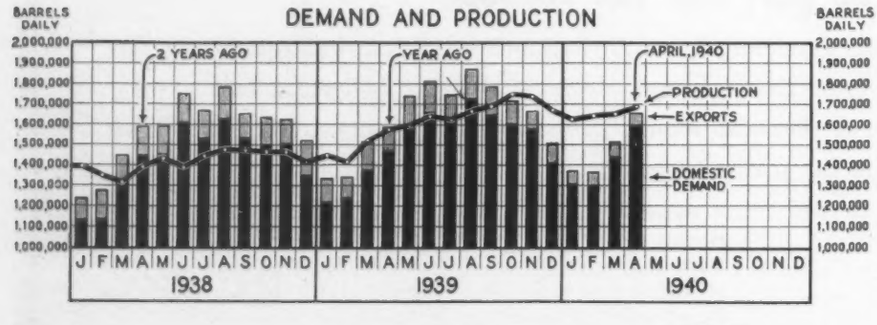
But the excess of gasoline is of such large size that any material improvement in the gasoline market likely will be slow and irregular.

The gasoline inventory appears to be at least 15,000,000 barrels larger than necessary, being still near 100,000,000 barrels, and liquidation of any substantial part of such a great surplus might be expected to require many months.

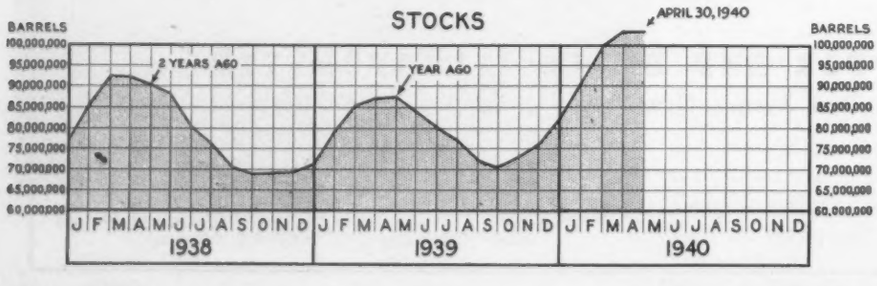
The problem probably will be made more difficult, moreover, rather than less difficult, when and if business in general responds to the national defense program. For the stepping up of industrial and

GASOLINE SITUATION

DEMAND AND PRODUCTION



STOCKS



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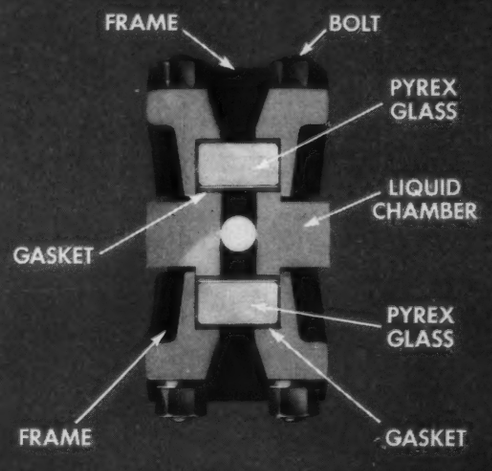

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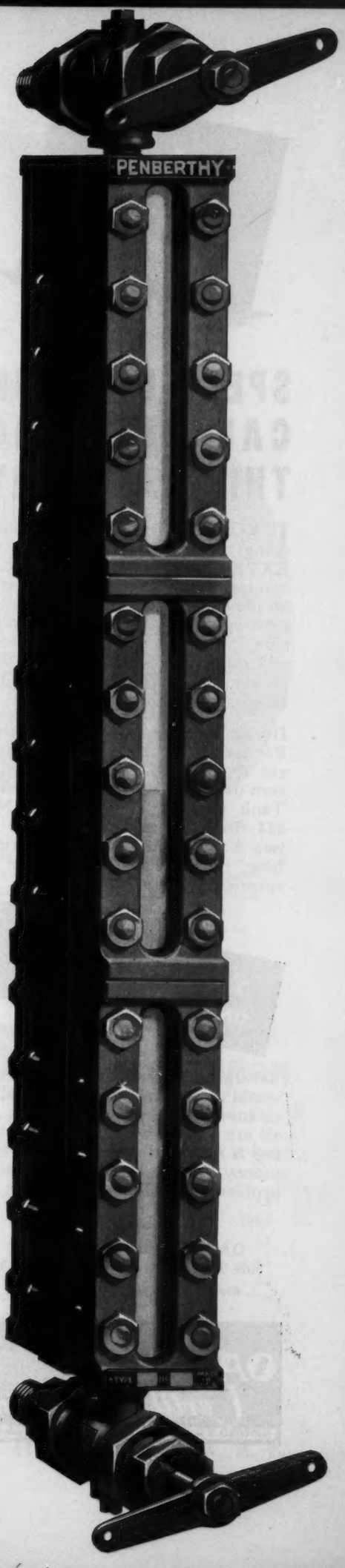

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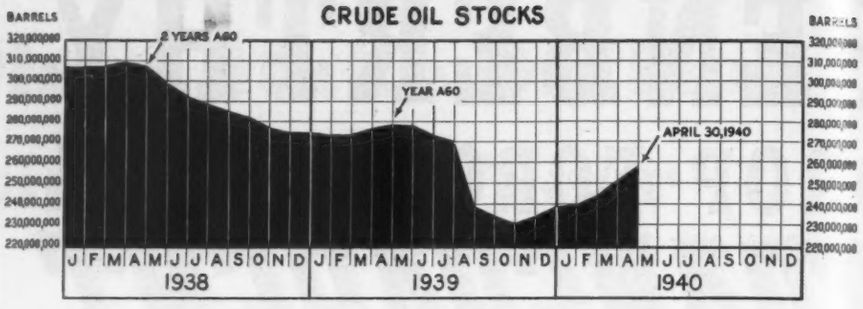

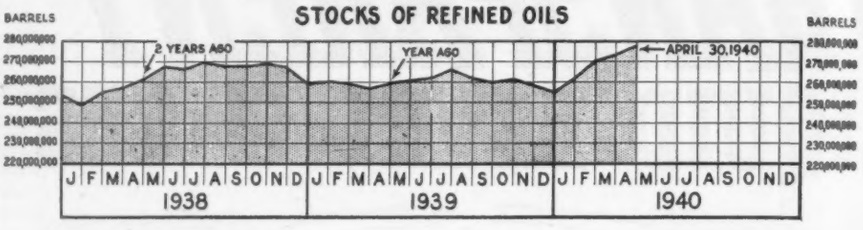
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BARRELS
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YEAR AGO
APRIL 30,1940
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1938
1939
1940

commercial activity may be expected to stimulate particularly the demand for lubricants, heavy fuel oils, and some other petroleum products and thus to require comparatively large crude runs to stills. And the brisk runs, in turn, would force large current output of gasoline at the refineries.

Meanwhile, the expectation of

Oil Demand Up in 1940 Despite Smaller Exports

Figures indicate barrels, and are from Bureau of Mines

	APRIL			FIRST FOUR MONTHS		
	1939	1940	Percent Change	1939	1940	Percent Change
SUMMARY—						
Total Demand	110,097,000	115,303,000	+ 4.7	440,237,000	471,124,000	+ 7.0
Daily average	3,670,000	3,843,000	+ 4.7	3,669,000	3,894,000	+ 6.1
Exports:						
Crude petroleum	6,222,000	4,262,000	— 31.5	20,475,000	15,837,000	— 22.6
Refined products	9,243,000	7,515,000‡	— 18.7	35,921,000	27,589,000	— 23.2
Total exports	15,465,000	11,777,000	— 23.9	56,396,000	43,426,000	— 22.9
Domestic Demand:						
Total domestic demand	94,632,000	103,526,000	+ 9.4	383,841,000	427,698,000	+ 11.4
Daily average	3,154,000	3,451,000	+ 9.4	3,199,000	3,535,000	+ 10.5
TOTAL DEMAND FOR PRODUCTS						
Motor Fuel:						
Domestic	43,977,000	47,683,000	+ 8.4	158,859,000	170,217,000	+ 7.2
Exports	3,663,000	2,075,000†	— 43.4	14,546,000	8,517,000	— 41.4
Total	47,640,000	49,758,000	+ 4.4	173,405,000	178,734,000	+ 3.1
Aviation Gasoline (included above):						
Domestic	*	209,000	.....	*	1,546,000	.....
Exports	323,000	302,000	— 6.5	1,450,000	831,000	— 42.7
Total	.....	511,000	.....	.....	2,377,000	.....
Kerosene:						
Domestic	5,042,000	5,621,000	+ 11.5	22,124,000	25,799,000	+ 16.6
Exports	713,000	399,000	— 44.1	2,601,000	1,573,000	— 39.6
Total	5,755,000	6,020,000	+ 4.6	24,725,000	27,372,000	+ 10.7
Gas Oils & Distillate Fuels:						
Domestic	10,856,000	12,210,000	+ 12.5	56,509,000	69,421,000	+ 22.8
Exports	2,345,000	1,966,000	— 16.2	9,075,000	7,067,000	— 22.1
Total	13,201,000	14,176,000	+ 7.4	65,584,000	76,488,000	+ 16.6
Residual Fuel Oils:						
Domestic	24,472,000	26,526,000	+ 8.4	106,940,000	116,371,000	+ 8.8
Export	1,488,000	1,532,000	+ 3.0	5,893,000	4,372,000	— 25.8
Total	25,960,000	28,058,000	+ 8.1	112,833,000	120,743,000	+ 7.0
Lubricants:						
Domestic	1,770,000	2,138,000	+ 20.8	7,019,000	7,597,000	+ 8.2
Exports	816,000	1,161,000	+ 42.3	3,176,000	4,511,000	+ 42.1
Total	2,586,000	3,299,000	+ 27.6	10,195,000	12,108,000	+ 18.8
Wax (pounds):						
Domestic	14,597,000	29,537,000	+ 102.3	82,900,000	101,095,000	+ 22.0
Exports	20,090,000	19,156,000	— 4.6	83,979,000	94,207,000	+ 12.2
Total	34,687,000	48,693,000	+ 40.4	166,879,000	195,302,000	+ 17.0
Coke (short tons):						
Domestic	78,900	86,700	+ 9.9	435,200	470,100	+ 8.0
Exports	23,100	13,500	— 41.6	51,500	49,300	— 4.3
Total	102,000	100,200	— 1.8	486,700	519,400	+ 6.7
Asphalt (short tons):						
Domestic	334,600	302,000	— 9.8	909,700	849,000	— 6.7
Exports	3,800	29,400	+ 674.0	17,300	91,700	+ 430.0
Total	338,400	331,400	— 2.1	927,000	940,700	+ 1.5
Road Oil:						
Domestic	267,000	190,000	— 28.8	848,000	501,000	— 40.9
Miscellaneous:						
Domestic	181,000	156,000	— 13.8	694,000	554,000	— 20.2
Exports	9,000	85,000	+ 844.4	31,000	462,000	+1388.0
Total	190,000	241,000	+ 26.8	725,000	1,016,000	+ 40.2

* Figures not available. †Includes benzol. ‡ Exclusive of 10,000 barrels exported from non-contiguous territories, but inclusive of 955,000 barrels shipped from United States to territories.

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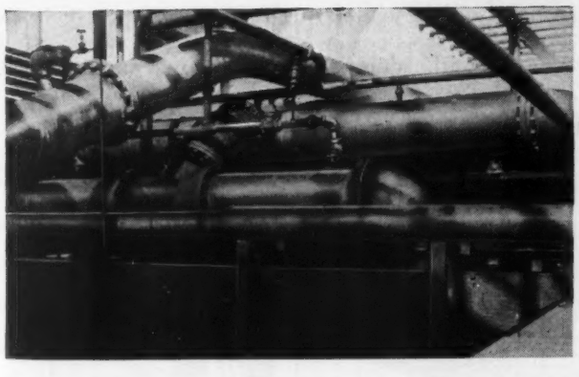
Cast iron tube sheets in oil still convection banks are subject to severe oxidation and early destruction. To avoid this expense, Winkler-Koch Engineering Co., Wichita, specifies these tube sheets in Ni-Resist, a corrosion and heat resistant alloy cast iron suitable for petroleum applications involving temperatures up to 1500° F. Carondelet Foundry, St. Louis, furnished the castings. Ni-Resist resists oxidation 5 to 10 times better than plain or low-alloy cast irons.



Winkler-Koch engineered this installation of Ni-Resist pipe for conveying vapors in condensing straight run gasoline. In refinery service, Ni-Resist shows from 2 to 60 times higher resistance than plain cast iron to corrosive liquids and gases. "For many services in petroleum refineries," writes Winkler-Koch, "Ni-Resist is by far the best alloy of any kind we have encountered. Ni-Resist trim, especially in contact with raw gasoline vapors or gasoline within range of condensation, has given much better service than other materials tried." Your inquiries are invited regarding money-saving applications of alloys containing Nickel.

—*Specify*

NI-RESIST* NICKEL CAST IRON

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A few comparative rates of corrosion on cast iron and on Ni-Resist

Corrosive Medium	*Ni-Resist*	*Cast Iron*
Hydrochloric Acid 5%	1	65.0
Sulphuric Acid 5%	1	190.0
Carbon Tetrachloride	1	2.0
Magnesium Chloride 10%	1	2.5
Sea Water (immersed)	1	4.0
Sea Water (spray)	1	12.0

*Ni-Resist—Reg. U. S. Pat. Off. by The International Nickel Company, Inc. —2278,180

Write for Nickel Cast Iron Data Sheet, Section 1, No. 4, "The Petroleum Industry Applies Ni-Resist."

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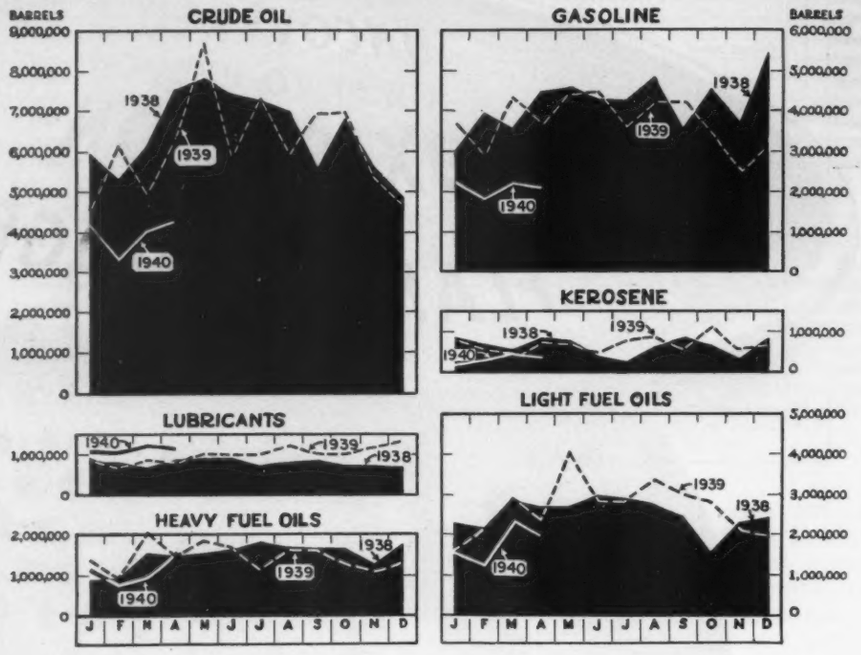

record-breaking consumption of heating oil next winter already constitutes an inflationary influence on refinery runs, and that influence will remain operative through the summer, fall, and winter.

In coming months, therefore, the need for definite efforts toward controlling gasoline stocks probably will be accentuated, rather than alleviated, despite the fact that large seasonal consumption will afford opportunity for liquidating surplus supplies.

The industry, consequently, will not be in position to relax the efforts it has been making heretofore toward a more economic inventory of gasoline by holding down the yields of that product, while taking proportionally larger yields of light fuel oils.

For the first three months of this year, oil companies reported exceptionally good earnings, having almost equaled the record for the corresponding period of 1937, one of the industry's most profitable years. For record volumes of business were transacted, with total demand greatest ever encountered,

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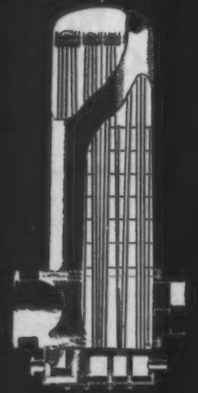

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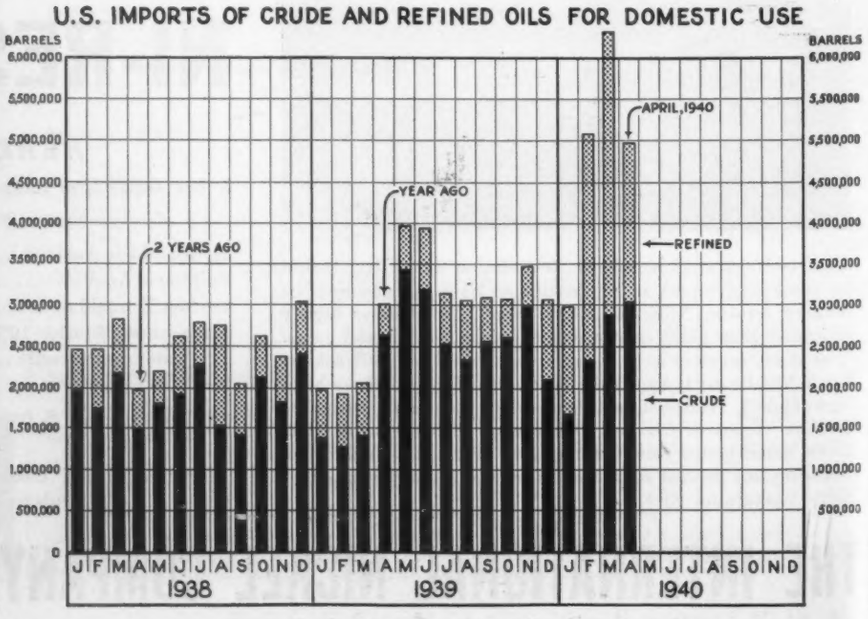
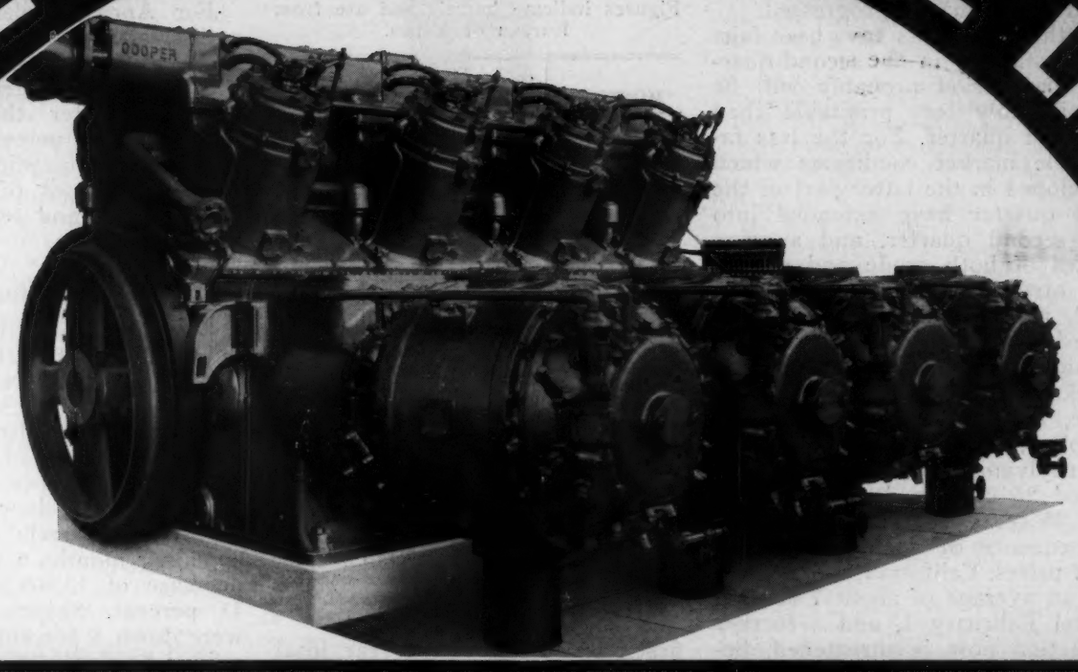


MORE HOURS ON THE LINE



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despite sharply curtailed exports; and prices of crude and refined oils were good, although they weakened as the quarter progressed.

Although results have been fairly satisfactory in the second quarter, the period probably will be considerably less profitable than the first quarter. For the less favorable market conditions which developed in the latter part of the first quarter have extended into the second quarter, and average prices of both crude and refined oils are lower in the current period, now practically at its end. The industry's markets have been particularly unsettled in recent weeks, and prices of fuel oils, kerosene, and lubricants, as well as gasoline, have declined. Prices of Pennsylvania grade crude were reduced 25 cents a barrel May 22 and 25 cents more on June 18, in consequence of declines in lubricant prices. California crudes were cut an average of about 7 cents a barrel February 1, and a further reduction now is threatened, because of the recent break in retail gasoline prices throughout the Pacific Coast region.

So far in 1940, demand for petroleum has exceeded the more conservative expectations. In the first four months of the year, total demand was 6.1 percent greater than in the corresponding months of 1939, on a daily average basis, as an increase of 10.5 percent in domestic demand far more than compensated for declines of somewhat over 20 percent in exports of both crude oil and refined products.

For April, similar trends prevailed, although gains over 1939 were somewhat smaller. During the month, total demand was 4.7 percent greater than in April, 1939, as a 9.4 percent increase in domestic consumption outweighed export decreases of 31.5 percent for crude oil and 18.7 percent for refined products.

Oil Imports for Domestic Use Up Sharply

Figures indicate barrels and are from Bureau of Mines.

MONTH	Crude Oil	Refined Products	Total
January:			
Jan., 1939....	1,373,000	609,000	1,982,000
Jan., 1940....	1,664,000	1,321,000	2,985,000
Percent Change.	+21.2	+117.1	+52.0
February:			
Feb., 1939....	1,266,000	654,000	1,920,000
Feb., 1940....	2,343,000	2,731,000	5,074,000
Percent Change.	+85.0	+320.0	+164.0
March:			
Mar., 1939....	1,404,000	659,000	2,063,000
Mar., 1940....	2,895,000	3,410,000	6,305,000
Percent Change.	+106.2	+417.4	+205.6
April:			
April, 1939....	2,648,000	366,000	3,014,000
April, 1940....	3,041,000	1,948,000*	4,989,000
Percent Change.	+14.8	+432.0	+65.5
1st 4 Months:			
1939.....	6,691,000	2,161,000	8,852,000
1940.....	9,943,000	9,410,000	19,353,000
Percent Change.	+48.6	+335.5	+118.7

* Exclusive of 43,000 barrels into territories.

Export Situation

Lubricating oil has been the only major oil export item that has moved out in increased quantity since the European war broke out. In the first 8 months of the conflict, total exports of United States crude and refined oils amounted to 103,833,000 barrels, compared with 116,834,000 barrels in the corresponding months a year earlier, a decrease of 13,000,000 barrels or 11 percent. Shipments of crude were down 8 percent and those of refined products 13 percent.

Changes From Year Ago in Stocks of Crude and Refined Oils in the United States

(Figures indicate barrels)

LATEST WEEKLY DATA

(Sources: Crude Stocks, Bureau of Mines; all other figures American Petroleum Institute.)

STOCKS OF:	June 24, 1939	June 22, 1940	Percent Change
Gasoline.....	81,331,000	97,276,000	+19.6
Gas Oil & Distillate..	30,794,000	32,751,000	+ 6.4
Residual Fuel Oil....	112,245,000	104,683,000	- 6.7
Crude Oil.....	[1]274,852,000	[2]259,800,000	- 5.5

LATEST MONTHLY DATA

(Source: Bureau of Mines.)

ITEM	Stocks at End of April		
	1939	1940	Percent Change
SUMMARY—			
Crude Petroleum:			
Refinable in U.S....	278,565,000	258,066,000	- 7.4
Heavy in California.	15,198,000	13,516,000	-11.1
Natural Gasoline.....	5,484,000	6,112,000	+11.5
Refined Products.....	268,565,000	277,739,000	+ 3.4
Total, all oils....	567,812,000	555,433,000	- 2.2
Day's supply:			
April Basis.....	155,000	145,000	- 6.7
PRODUCTS—			
Gasoline:			
Finished.....	81,623,000	96,615,000	+18.4
Unfinished.....	5,908,000	6,984,000	+18.2
Total.....	87,531,000	103,599,000	+18.3
Kerosene.....	5,663,000	4,351,000	-23.2
[3]Gas Oil & Distillate Fuels.....	21,058,000	20,310,000	- 3.6
[3]Residual Fuel Oils...	90,411,000	83,825,000	- 7.3
Lubricants.....	7,886,000	8,065,000	+ 2.5
Wax (pounds).....	119,301,000	96,910,000	-18.8
Coke (short tons)...	734,000	663,000	- 9.7
Asphalt (short tons)..	688,000	768,000	+11.6
Road Oil.....	1,048,000	1,145,000	+ 9.3
Miscellaneous.....	283,000	407,000	+43.8
Other Unfinished Oils.....	37,732,000	38,299,000	+ 1.5

[1] Stocks on hand June 17, 1939.
[2] Stocks on hand June 15, 1940.
[3] At refineries only.

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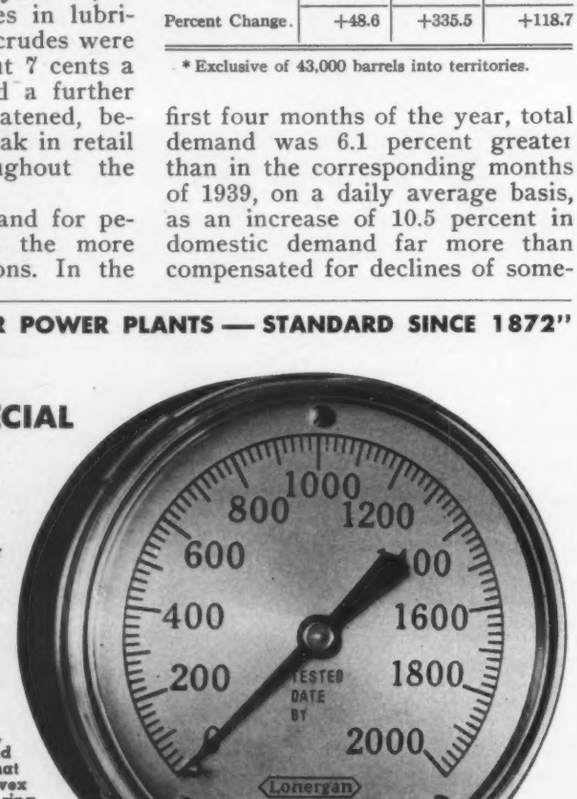

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Pennsylvania Officials Elected

Parker L. Melvin, Towne-Melvin Oil Company, Bradford, was elected president of the Pennsylvania Grade Crude Oil Association, June 21 and 22 at Bradford. He succeeds W. F. Clinger, Clinger Oil & Gas Company, Tidioute, who remains on the board of directors.

Other officials are:

A. E. Booth, Bradford, first vice president; O. W. Walchli, Wellsville, New York, second vice president; Samuel Messer, Quaker State Oil Refining Corporation, Oil City, treasurer; W. R. Reitz, Quaker State Oil Refining Corporation, Oil City, assistant treasurer; John A. Beck, Pennsylvania Refining Company, Butler, corresponding secretary; J. E. Moorhead, executive secretary; S. F. Pratt, assistant secretary, and F. B. Dow, general counsel.

Directors named besides Clinger, are: D. T. Andrus, Bradford; Beck; Booth; E. C. Breene, Oil City; W. J. Brundred, Brundred Oil Corporation, Oil City; H. M. Carruth, Canfield Oil Company, Cleveland; E. M. Craig, Freedom Oil Company, Freedom; C. R. Daugherty, Butler; A. D. David, Bradford-Penn Refining Company, Clarendon; C. M. Davison, Standard Oil Company of New Jersey, New York; W. J. Healy, Healy Petroleum Company, Bradford; D. E. Hoffman, Tide Water Associated Oil Company, New York; Otto Koch, Kendall Refining Company, Bradford; H. R. Lewis, Conewango Refining Company, Warren; H. A. Logan, United Refining Company, Warren; D. B. McCalmont, Franklin; John McCoy, Columbus, Ohio; Melvin; Messer; F. E. Richart, Wellsville, New York; D. T. Ring, Preston Oil Company, Columbus, Ohio; C. E. Streeter, Bradford; C. L. Suhr, Pennzoil Company, Oil City; T. P. Thompson, Jr., Bradford; S. M. Vockel, Waverly Oil Works Company, Pittsburgh, and Walchli.

W. P. R. A. Meeting Dates Announced

Technical meetings of the Western Petroleum Refiners Association will be held October 4 in Wichita and October 25 in Shreveport. The programs will be technical and will be arranged by the committee of which L. D. Mann, Cities Service Oil Company, Bartlesville, is chairman. The Shreveport meeting will be under auspices of the Ark-La-Tex Division, which has headquarters at Shreveport.

Armour Institute Catalysis Course

A summer course in catalysis is being conducted at Armour Institute, Chicago, with the application of this new phase of chemistry as adapted to petroleum refining a major part of the study. Dr. Jacque C. Morrell, associate director of research, Universal Oil Products Company, and Dr. V. I. Komarswky, a member of the U. O. P. research staff and a professor at the school, are on the faculty for the 12 weeks from June 15.

These men will conduct the course as catalysis applies to petroleum refining. From oil, catalytic reactions are now the source of aviation gasoline, synthetic rubber and toluene, a raw material for the manufacture of TNT.

The Look Box

Additives Permitted Under Pennsylvania Emblem

Permission to use efficient additives in limited concentration in emblem oils has been granted to refiner and jobber members of the Pennsylvania Grade Crude Oil Association. It is understood that the association does not approve any particular agent but merely extends the privilege of using such materials in emblem oils to its membership. The use of additives is regarded as a move to improve, not cheapen, the product.

This permission will be entirely a matter of choice for the individual member and the association will not require any licensee to use such agents. Numerous tests on the effects of using such addition agents have been made in the association's laboratories and in those of its members.

Granting of this permission does not alter in any way the existing regulations of the association with respect to the specifications necessary to meet established standards. All of these standards remain in effect.

Supply Group to Support Texas Meeting

If the 1941 meeting of the Natural Gasoline Association of America is held in Dallas, as anticipated, the Natural Gasoline Supply Men's Association will provide entertainment as has been the custom for the meetings, all previously held in Tulsa. This was one of the decisions of the first meeting of the supply organization held June 10 in Tulsa. Officials, elected at the membership meeting May 15 in Tulsa, were installed.

Another decision was to sponsor a revised printing of the technical manual in 1941. The volume will have 16 pages of new technical data, which will replace 16 pages of the manual, last printed in 1937. It is planned to print 2000 copies. A publications committee of D. E. Fields, William Bego and W. W. Woobank, was named. An advisory committee from the natural gasoline association was asked for in a motion.

A new membership committee, Egon Koehler, R. T. Roberts and George W. Probst, was named and instructed to seek new members from Texas and Louisiana.

Oil Into Defense Plans

The petroleum industry came into the program of national defense with the selection of Dr. R. E. Wilson, president of Pan American Petroleum and Transport Company, New York, to represent this industry on the Industrial Advisory Commission of the Council of National Defense. He will work under the supervision of Edward R. Stettinius, former chairman of United States Steel Corporation, who has charge of raw materials on the commission.

Dr. Wilson will have headquarters in Washington, where a staff will be assembled to supervise coordination of a petroleum supply for national defense needs. Shortly after the appointment he announced that the industry was in good condition for providing necessary fuel.

Other phases of the status of the petroleum industry will involve drawing upon other phases of defense activity in order to assure supplies. Outstanding among these is the protection of refining plants. The major part of the nation's refining capacity is concentrated on its coasts. Protection from aircraft bombing is essential to operation of the plants. Since not only aviation gasoline, other petroleum fuels, raw material for synthetic rubber and even a material for high explosives can come out of petroleum, refining plants are comparable to munition plants for materials, and would be one of the first objectives of enemy bombers.

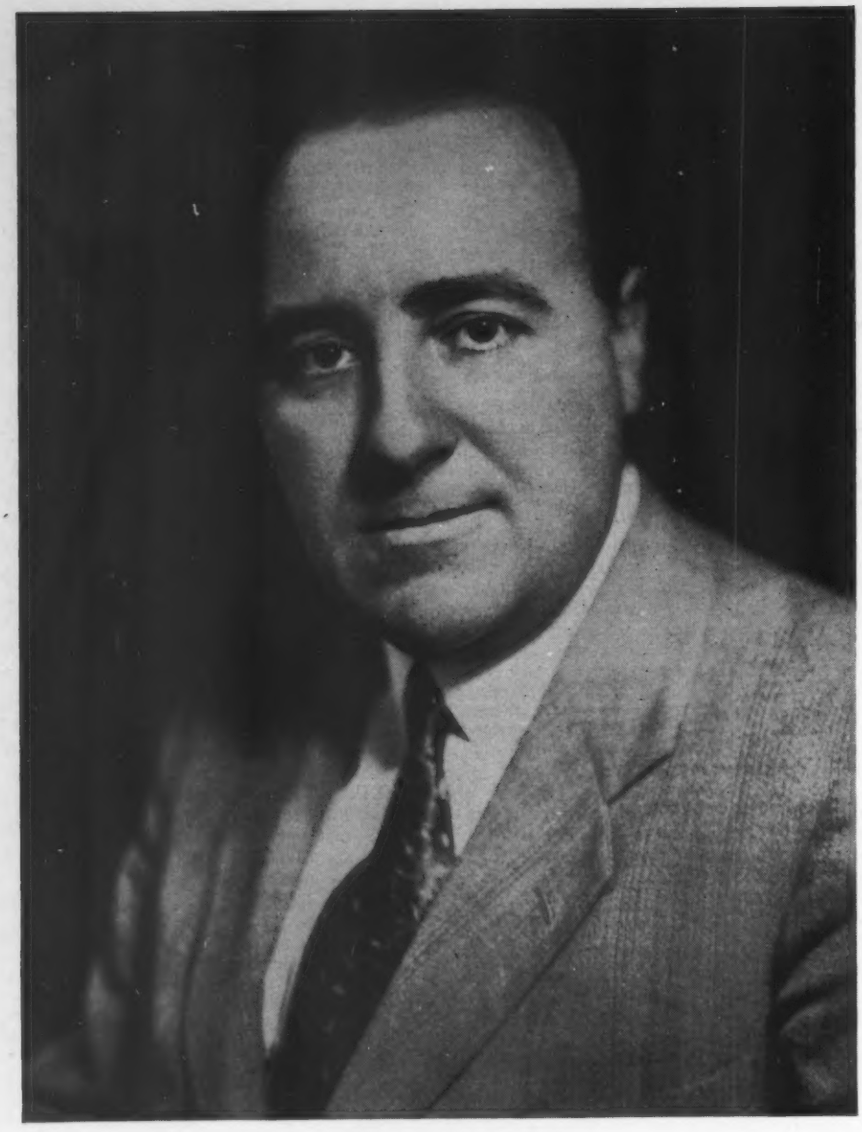
Furthermore it is the larger plants, which will contribute most of these materials and the larger plants offer favorable targets. The Texas Gulf Coast from Port Arthur to Corpus Christi with its flat terrain is typical of the defense necessity.

Administration officials also are concerned with the unfavorable market situation, particularly in view of heavy stocks, which are overhanging the industry and threatening its price stability. This has been aggravated by loss of export markets with the turn of the war in Europe.

The attitude in Washington is that a reduction of stocks to a point where more orderly operations can be maintained, with oil moving from the well

CONVENTIONS

SEPT.	
3– 5	**American Society of Mechanical Engineers, Spokane, Washington.**
9–13	**American Chemical Society, Detroit.**
18–20	**National Petroleum Association, Hotel Traymore, Atlantic City.**
30	**National Lubricating Grease Institute, Stevens Hotel, Chicago.**
OCT.	
1	**National Lubricating Grease Institute, Stevens Hotel, Chicago.**
3– 5	**North American Gasoline Tax Conference, Whitley Hotel, Montgomery, Alabama.**
7–10	**American Gas Association, Atlantic City.**
7–11	**National Safety Congress and Exposition, Stevens Hotel, Chicago.**
NOV.	
1	**California Natural Gasoline Association, Los Angeles.**
11–15	**American Petroleum Institute, Stevens Hotel, Chicago.**
DEC.	
1– 6	**Exposition of Chemical Industries, Grand Central Palace, New York.**
2– 6	**American Institute of Chemical Engineers, New Orleans.**



DR. ROBERT E. WILSON

Selection of Dr. Robert E. Wilson, president of Pan-American Petroleum and Transport Company, to represent the oil industry on the Industrial Advisory Commission to the Council of National Defense came after several plans had been under consideration by the president. It will be the duty of his department to see that the oil supply is adquate for needs of the program.

The choice met with instant approval within the industry. Dr. Wilson is both an outstanding scientist and a successful executive. He was born at Beaver Falls, Pennsylvania, March 19, 1883. After graduation from Wooster College in 1914, he entered Massachusetts Institute of Technology and was graduated in 1916. He was research associate in applied chemistry at that school in 1916 and 1917, and also worked in the research laboratory of the General Electric Company.

In 1922, he joined Standard Oil Company (Indiana) and was assistant director of research until 1928. In 1929 he became assistant to the vice president in charge of manufacturing, later becoming a director and vice president in charge of research and development. He was elected vice president of Pan-American Petroleum & Transport Company in 1934, and later became its president.

He was awarded the Chemical Industry Medal for 1939 at a joint meeting of the American Section of the Society of the Chemical Industry, the New York Section of the American Chemical Society and the New York Section of the American Institute of Chemical Engineers.

to consumer without long stop-overs in storage, would be preferable to further dangerous increases in above-ground supplies. While, in the event of an emergency, above-ground stocks might prove highly valuable, the belief in Washington is that the national defense program will not reach the point where large quantities of oil will be required for some time and that, in the meantime, it would be better if there was nothing to threaten the price situation and stability of the industry.

So far as the oil industry is concerned, it is said, no other serious problems have been raised so far. It is recognized that a supply of crude oil adequate for any need can be secured overnight by removal of proration restrictions in the leading producing states, that refinery output can be stepped up just as easily and, if needed, additional capacity constructed with little delay.

July Demand Estimate Reflects Export Loss

Demand for crude oil in July for domestic uses was set at 3,628,400 barrels daily by the United States Bureau of Mines. The estimate is 23,600 barrels lower than that set for July, 1939, but 8100 barrels higher than the estimate for June, 1940. Loss of export markets was responsible for the lower 1940 estimate.

Daily average crude-oil production and runs to stills during the four weeks May 5 to June 1 were 3,787,000 and 3,629,000 barrels, respectively. During this period domestic crude stocks increased an average of 103,000 barrels daily, indicating a demand of 3,684,000 barrels per day, compared with 3,601,000 barrels estimated by the bureau. However, the gasoline stock decrease was less than half that forecast by the bureau.

The increase in the domestic demand for motor fuel is being offset by the severe decline in exports so that the total demand in the third quarter may be less than 3 percent above last year. This situation, coupled with the high inventories of gasoline, normally would indicate a curtailment of runs. However, this objective has not been attained because of the relatively large demand for light fuel oils and the necessity of building up depleted stocks. To correct this situation low gasoline yields and high distillate yields are indicated as essential.

For August and September, no substantial increase in crude runs to stills over July is anticipated. The decline in crude exports is offsetting the increase in runs and the total demand for domestic crude oil may be less than last year.

Motor Fuel

The estimated domestic demand for motor fuel is 54,800,000 barrels, a gain of 8.5 percent over the demand for July, 1939. This indicated increase is comparatively high because last year's demand was abnormally low; actually, the general trend in domestic demand for motor fuel is only about 6 percent higher than a year ago.

Forecasts by the principal exporters of motor fuel indicate that foreign shipments of motor fuel will be very low for July. The bureau has estimated the total for that month at 2,000,000 barrels, which is 400,000 barrels less than the June estimate and 1,585,000 barrels less than the actual exports in July, 1939.

Stocks of finished and unfinished gasoline on April 30 were 103,563,000 barrels. Statistics of the American Petroleum Institute show a decrease of only 1,940,000 barrels during May, which would make these stocks approximately 101,600,000 barrels as of May 31, an amount far above the level of a year ago. If the industry continues to run sufficient crude to supply the demand for other oils, adequate reduction in gasoline stocks can not be made at the present yields. The bureau estimates a possible reduction of 5,600,000 barrels in finished gasoline stocks in July.

Benzol and direct sales of natural gasoline are estimated as 1,100,000 barrels, making refinery production of gasoline 50,100,000 barrels. This is distributed among the various districts as follows (thousands of barrels): East Coast, 6720; Appalachian, 1930; In-

POWER...*assumed*...real

Canute, King of England, Norway and Denmark wearied of the flattery of his courtiers, who held him all-powerful. To teach them otherwise, he commanded the tide to stand still . . . and they quickly learned that he had no power over natural forces. The water . . . under the pull of the moon's gravitation . . . would not halt . . . but moved inexorably toward the disillusioned group.

Oversized pigment particles in enamels, water or wax in petroleum stocks, and other undesirable matter . . . subjected to the pull of Centrifugal Force, when passing thru a Sharples Centrifugal . . . all must feel as bewildered and helpless as did this Royal Group.

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diana-Illinois, 10,050; Oklahoma, 2810; Kansas-Missouri, 2630; Inland Texas, 3630; Texas Gulf Coast, 12,400; Louisiana Gulf Coast, 1500; Inland Louisiana-Arkansas, 890; Rocky Mountain, 1350; California, 6190.

Crude Petroleum

Natural gasoline to be blended at refineries is estimated as 5.55 percent of the total refinery gasoline production, or 2,780,000 barrels. The yield of straight-run and cracked gasoline, in order to provide for the demand for other oils, is estimated at only 43.1 percent. The application of this yield to the production of 47,320,000 barrels of gasoline gives crude runs of 109,780,000 barrels, or 3,541,300 barrels daily. Foreign crude runs are estimated as 3,200,000 barrels.

Canada, France, and Japan have been the principal foreign markets for United States crude oil. Exports to France have averaged more than a million barrels monthly for the first four months of this year. Recent war developments not only will curtail this market but may force oil, formerly marketed in France from other countries, into competition with United States' oil in its remaining export markets. The bureau estimates that crude exports in July will be 3,700,000 barrels, or 900,000 barrels less than the June forecast and 3,600,000 barrels less than the actual exports for July, 1939.

The estimate for crude oil to be used for fuel and losses for July is 2,200,000 barrels.

The breakdown of the total estimated daily demand for domestic crude oil of 3,628,400 barrels gives the following crude requirements by states of origin. As these requirements may be supplied either from stocks or from new production, contemplated withdrawals from crude-oil stocks must be deducted from the bureau's estimate of demand to determine the amount of new crude required. These estimates are not recommendations for production but represent the projection of actual market trends by states:

TABLE 1

ESTIMATED DAILY AVERAGE CRUDE-OIL DEMAND BY STATES (Barrels)

(As no changes in crude-oil stocks are involved in these estimates, they represent demand rather than production)

STATE	Forecast July 1940	Forecast June 1940	Actual July 1939
Texas	1,339,400	1,344,600	1,448,000
California	593,900	593,700	616,000
Oklahoma	403,900	408,600	427,000
Illinois	402,300	395,600	261,000
Louisiana	278,100	274,700	269,000
Kansas	159,400	159,000	182,000
New Mexico	106,100	106,700	127,000
Wyoming	80,600	73,000	67,000
Arkansas	67,400	66,700	58,000
Michigan	61,600	62,000	73,000
Pennsylvania	47,900	49,400	47,000
Montana	18,100	18,300	18,000
Kentucky	14,200	15,000	13,000
New York	14,000	14,000	10,000
West Virginia	10,000	11,000	11,000
Mississippi	9,700	7,000	...
Indiana	9,000	8,000	4,000
Ohio	8,000	9,000	17,000
Colorado	4,800	4,000	4,000
	3,628,400	3,620,300	3,652,000

William S. Scully, has resigned as counsel and general manager of the Independent Refiners' Association of California, Inc., to engage in private law practice in Los Angeles. He will continue to serve the association in its legal activities. Donald B. Neill, who has been with the association several years, will become general manager.

Butyl Rubber Announced By Esso Laboratories

Discovery of Butyl rubber in the Esso Laboratories of Standard Oil Company of New Jersey was announced at the June meeting of stockholders of the company by W. S. Farish, president. The discovery was classed as a companion of Buna rubber, a synthetic product originated by I. G. Farbenindustrie, A. G. of Germany, to which Standard Oil Company of New Jersey has American rights. A Buna plant is under construction at the Baton Rouge plant of Standard Oil Company of Louisiana.

Butyl rubber is more nearly a straight petroleum product than its companion. The process is more direct and simple and Butyl is expected to be lower in cost. A semi-commercial plant is in operation in the Esso laboratory at Bayway, New Jersey.

Concerning the products the announcement read:

"Both Buna and Butyl synthetic rubbers are superior to natural rubber in respects which are undoubtedly of importance in tire manufacture. Should it become necessary for the United States to produce synthetic rubber in substitution for a major portion of imported natural rubber, the Jersey company is in position to manufacture Butyl rubber from petroleum in any required quantities as rapidly as the necessary plant facilities can be installed.

Refining Plants Show Increase

The number of refining plants in the United States stood at 547, January 1, 1940, showing the first increase in the number of domestic plants in four years. The increase over 1938 was only nine. The figures were released by the United States Bureau of Mines in early June.

Although the number of plants is far below the records of 1934, 1935 and 1936, the number of operating plants, 461, is the highest ever recorded by the Bureau of Mines Survey. The number of idle plants continued to decline and stood at only 86 as of January 1.

The following summary of the report is from Bureau of Mines Information Circular 7142, which was compiled by G. R. Hopkins and E. W. Cochrane:

"Of the 547 completed plants on January 1, 1940, 461 were operating at least in part, and 86 were shut down. The number of operating plants is the highest ever recorded, being 7 above the previous record of January 1, 1934. On the other hand, the number of idle plants continued to decline; 86, as of January 1, 1940, is far below the peak of 210, as of January 1, 1936, when many refiners in East Texas were going out of business. An unusual feature of the increase in number of operating plants during 1939 was that virtually all the gains were made in the Central States as the result of the spread of oil discoveries. The Indiana-Illinois district is advantageously situated for refineries, but few of those built before 1938 were located on the basis of crude-oil supply. The drop of 17 in the number of idle plants was due mainly to dismantling in California and Texas.

"Daily average crude runs to stills increased from 3,192,000 barrels in 1938 to 3,391,000 in 1939. The operating capacity rose from 3,933,785 barrels daily on January 1, 1939, to a new high of 4,196,694 barrels on January 1, 1940. At the same time, the idle capacity declined from 574,770 barrels to 431,952. These data indicate that increased demand, both actual and speculative, not only led to a material amount of new construction but caused a comparable amount of idle equipment to be placed in service. The highest daily throughput of crude oil in 1939 occurred in October and was about 3,700,000 barrels, indicating that about 900,000 barrels of capacity was idle on that day. This excess includes the idle capacity of 431,952 barrels, of which 360,897 barrels was reported in good shape and 71,055 barrels in poor shape as of January 1, 1940. Probably most of the excess capacity is obsolete when viewed in the light of present standards for gasoline, lubricants, and special products; however, with stocks of gasoline more than ample and with emphasis on production of heating oil, the old straight-run equipment, comprising most of the excess capacity, now constitutes more of a reserve than would have been the case a year ago.

"The amount of new construction continued to decline, as new construction as of the first of the year fell from 142,250 barrels to 92,567, and as the capacity added during the year rose only from 378,350 barrels in 1938 to 380,866 in 1939. These data cover only crude-oil capacity and not auxiliary equipment, such as that used for polymerization, alkylation, and solvent extraction. The nature of the new construction changed radically in 1939, as on January 1, 1940, all but 725 barrels of the 92,567 barrels of new construction was 'additional,' whereas the major part of that under way on January 1, 1939, was for replacement.

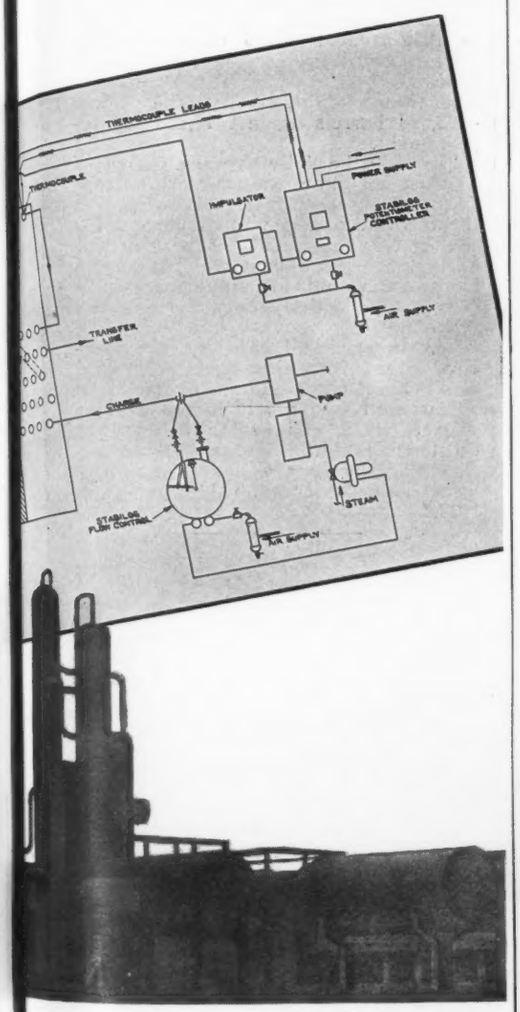
"The trends in operating capacity by refining districts in 1939 were similar to those in 1938, with the Indiana-Illinois and Texas Gulf Coast showing the largest increases. Three districts—Oklahoma-Kansas, Louisiana Gulf Coast, and Arkansas-Louisiana Inland—reported a decline in operating capacitity in 1939. The Indiana-Illinois district had nearly two-thirds of the new construction under way on January 1, 1940. The Texas Gulf Coast had only 9500 barrels under construction on that date, which was almost as noteworthy as California, with only 500 barrels under way.

Decline in Texas

"Texas' share of the completed capacity declined to just below 30 percent in 1939, although it remains far ahead of California, which is in second place. The most important change in the rank of the states in crude-oil capacity was the rise of New Jersey to fourth place from sixth, displacing both Indiana and Oklahoma.

"About three-fifths of the refineries ar skimming or skimming and cracking plants—that is, plants devoted primarily to manufacture of gasoline. The increase in the number of operating plants and the decline in the number of idle plants in 1939 mainly affected these two types of plants, as the net change in the number of other types was small. Although the capacity of

weaken



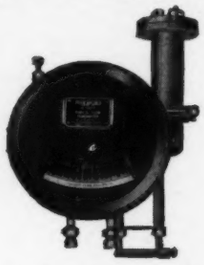
THE PRODUCT

FOXBORO INSTRUMENT RECORD

Remote Flow Control Uses Safe Pneumatic System

Foxboro's safe system for remote flow measurement and control, using compressed air for the transmitting medium, has found particular favor in refinery operations and other processes where fire and explosion hazards are encountered.

With this system, measurement can be transmitted to one or more receivers as far as 500 feet from the point of origin. Positive assurance of perfect agreement is inherent in the hook-up

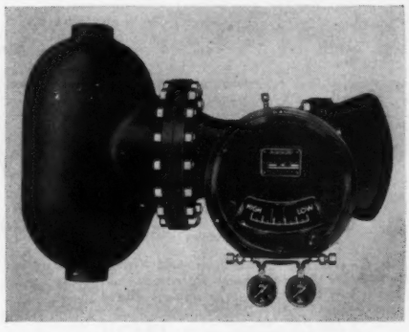


employed. Nevertheless, the system is simple and economical to install, using standard Foxboro air-operated mechanisms.

Why not call on the Foxboro Field Man to check on the advantages of centralizing recording and control instruments in your plant? (*Foxboro Bulletin 727*)

Stabilog Liquid Level Controller Offers Unique Averaging Action

Among instruments especially designed by Foxboro for control of liquid level, the Ball-Float Type of Stabilog Liquid Level Controller has built up an outstanding performance record. It provides positive response to minute vari-



ations in level, while at the same time it is able to meet drastic demands for *averaging control action* where conditions make such action desirable.

Averaging control action, as made possible by the Stabilog system of control, allows input surges to be absorbed within the vessel as a temporary variation in level within permissible limits, while constantly working to bring about the return of the level to normal. In other words, it is a liquid level control which takes into consideration the need for smooth outflow as well as the maintenance of optimum level conditions. Even when the initial upset in input has been abrupt, the *rate of change* back to equilibrium conditions is so controlled that abrupt outflow changes do not occur.

In addition, mechanical features of the Ball-Float unit make for accurate and trouble-free service. The stainless steel ball-float is so counterbalanced on a knife-edge bearing that there is no change in the immersion level of the ball due to friction or no lag in responsiveness due to its weight. The patented Foxboro Pressure-Tite bearing requires neither packing nor adjustment and practically eliminates friction. *As there is no lost motion in the entire movement,* the slightest change in level is reflected in smooth and accurate response. (*Foxboro Bulletin 210*)

Continuous Process Control Calls for Stabilog System

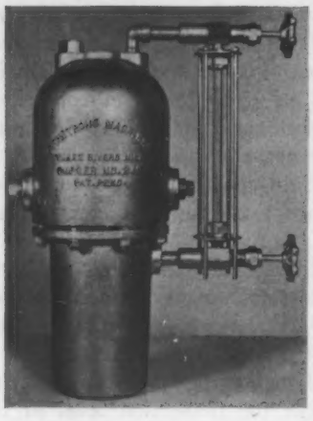
Why have Stabilog Controllers found such wide and enthusiastic acceptance for industrial processes involving continuous flow of fluids? The answer is simply that the use of Stabilog Con-

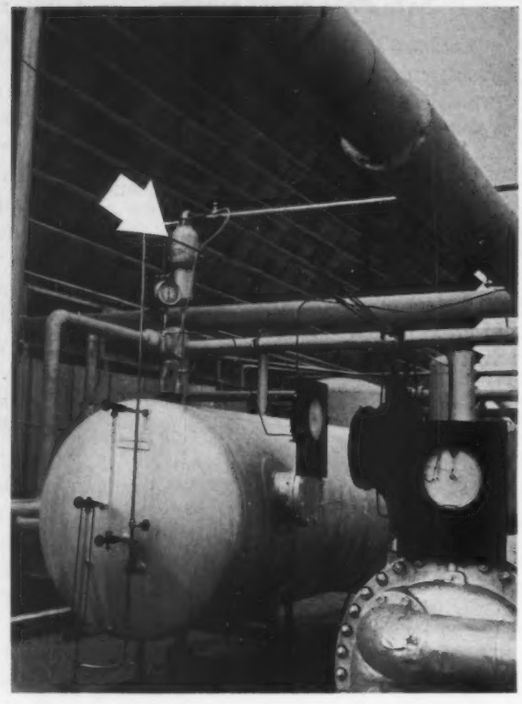
trollers results in *smooth* operation. Surges are prevented or quickly ironed out and the process is held in balance. All this is done automatically and accurately.

The theory of this control system, as well as a description of the mechanical features of Stabilog Controllers which assure dependability in service, are described in an interesting 32-page bulletin, "Stabilog Process Control in Industry." (*Foxboro Bulletin 175-1*)

Refiner Finds New Way to Purify BUTANE

USED IN REFRIGERATION SYSTEM





Installs New ARMSTRONG PURGER!

REFINERS who produce butane, propane, isobutane, etc. and/or use them as refrigerant gas in refrigerating equipment will be interested in the installation pictured above in a Texas refinery. This company produces butane and also uses it in a refrigeration system for cooling natural gasoline and mineral seal oil.

Formerly, it was impossible to purify the butane sufficiently to remove traces of propane, ethane and methane. As a result, the high side (condenser) pressure in the refrigerating system always ran about 10 lbs. above the normal condensing point. This increased the power bill about 5%.

Today, that power waste has been eliminated and the butane is virtually PURE—thanks to a new invention "The Armstrong Non-condensible Gas Purger!" This unit has wide applications for purifying condensible gases and for raising the efficiency of refrigerating systems.

Write for interesting new bulletin...JUST OFF THE PRESS.

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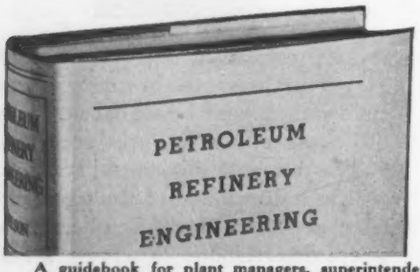

Petroleum Refinery Engineering

By W. L. NELSON

Consulting Petroleum and Chemical Engineer
Professor of Petroleum Refining,
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647 pages, 6 x 9, 185 illustrations
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A guidebook for plant managers, superintendents, chemists, engineers, and other refinery men. Provides a complete engineering treatment of petroleum processing, emphasizing its relation to chemical engineering. Covers fundamentals, many details of the design and operation of petroleum equipment, economical aspects, etc. Includes illustrations or examples of almost all important calculations.

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the 70 complete plants was nearly half of the total capacity on January 1, 1940, the gain in capacity in 1939 was mainly in the skimming and cracking and topping and cracking categories. The proportion of the active capacity without cracking facilities increased in 1939 but this is probably a temporary matter related to the construction of skimming plants in the Central States.

Cracked-Gasoline Capacity

"The capacity of the active cracking units continued to increase in 1939 and on January 1, 1940, amounted to 964,665 barrels daily, or 10 percent above the capacity the previous year compared with a 7-percent gain in the capacity of the active crude-oil units. As with crude-oil capacity, the idle cracking capacity declined in 1939; however, the capacity of the cracking units under construction on January 1, 1940, was somewhat higher than on January 1, 1939, whereas the crude-oil capacity under construction on the two dates dropped materially. The capacity added in 1939 totaled 67,699 barrels against only 13,,850 barrels retired. The major portion of the capacity under construction on January 1, 1940, was additional —43,925 barrels against 14,150 for replacement.

"In 1939 the daily average output of cracked gasoline was 809,000 barrels, from which it may be calculated that the operating ratio was 88 percent for the active units and 79 percent for both active and inactive equipment. These ratios indicate some increase in comparative activity over the previous year.

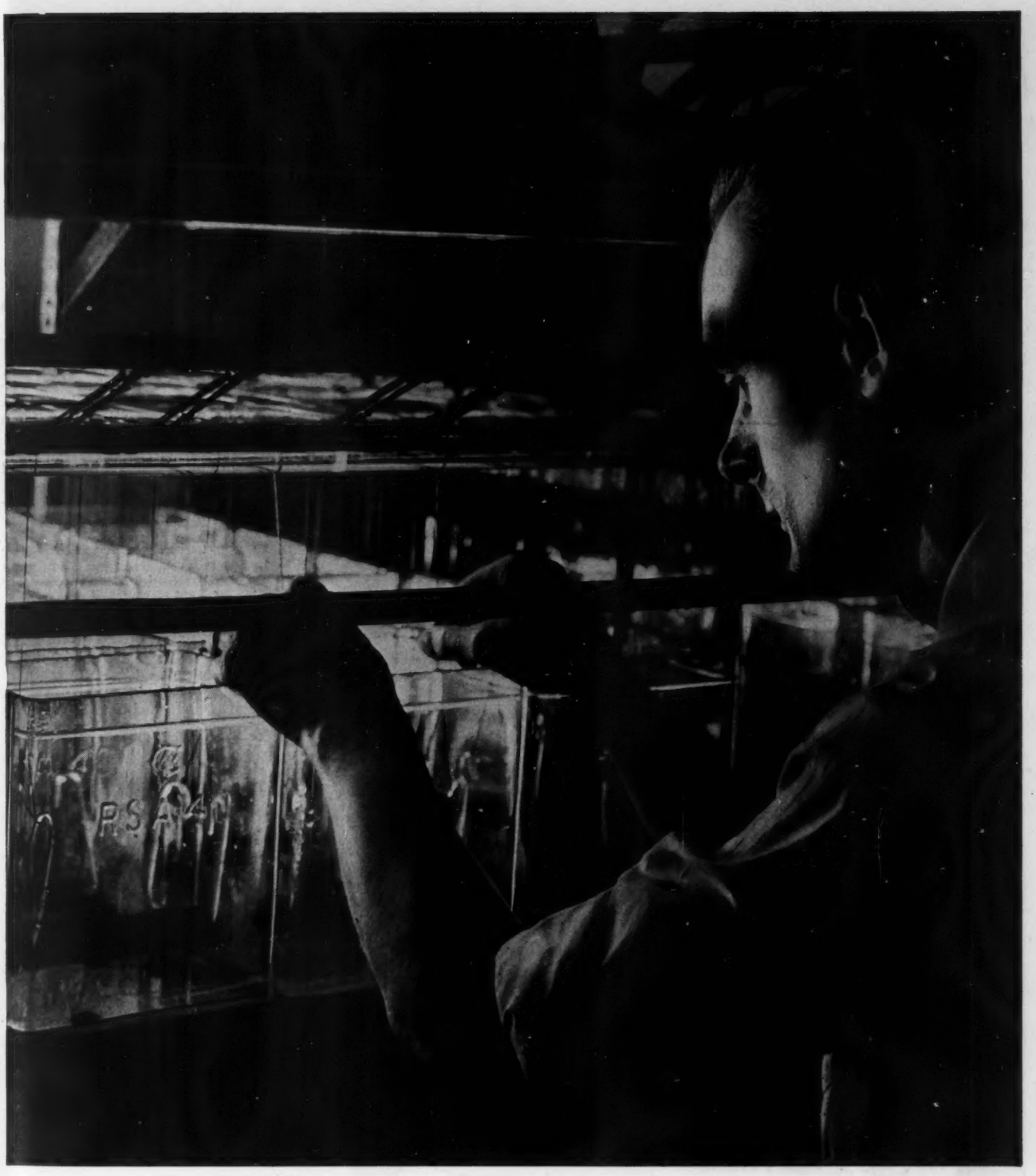
"As in crude-oil capacity, the principal gain in cracking capacity in 1939 was in the Indiana-Illinois district. The Texas Gulf Coast, which had a large gain in 1938, changed little in 1939. California showed an unexpected decline and the East Coast an unusually large gain in completed capacity in 1939."

Frank W. Adams, who has been president of Standard Oil Company of New Jersey (incorporated in Delaware) was elected a director of the parent company along with Eugene Holman, president of Creole Petroleum Company and Lago Petroleum Corporation. G. H. Smith, president of Imperial Oil Company, Ltd., resigned from the board.

Adams headed the manufacturing subsidiary of Standard Oil Company (New Jersey) in 1933. He has been connected with the organization and subsidiaries since 1912, when he worked as a draftsman in the Eagle Works at Jersey City. He became superintendent of that plant and in 1922 became manager and a member of the manufacturing committee, and had charge of the Parkersburg, West Virginia, plant. In 1926 he became general manager of the three New Jersey plants.

L. L. Davis, process supervisor for Continental Oil Company, Ponca City, Oklahoma, led the group discussion on "Oxidation of Lubricants," a part of the program of the summer conference of the American Association for the Advancement of Science, Gibson Island, Maryland, June 20.

The first week of the conference, which began June 17, was devoted to "Frontiers of Petroleum." The conference will continue through August 4.



Unending research develops Chase alloys to meet the changing needs of industry. The Chase metallurgist in the photograph is testing the corrosive action of various solutions on condenser tube alloys. Through such careful tests was developed Chase Antimonial Admiralty (described on the opposite page) to counter the destructive forces that cause dezincification in condenser tubes. Perhaps Chase engineers can help you stretch the time between tube replacements.

CHASE

CHASE CONDENSER TUBES

Ten Safe and Profitable Years

When the calendar came to June 13, 1940, the natural gasoline plants of Shell Oil Company at Braman and Tonkawa, Oklahoma, wound up 10 years of "continuous operation without a disabling injury to any employe." Man hours during the period were 620,700.

Of the 20 regular employes at the two plants, eight participated in the record: William R. Butler, Roy M. Hamman, Oliver W. Hollingsworth, H. T. Renfrow, Albert R. Stout, George D. Taylor, Milton K. West and Tarance T. Whitley.

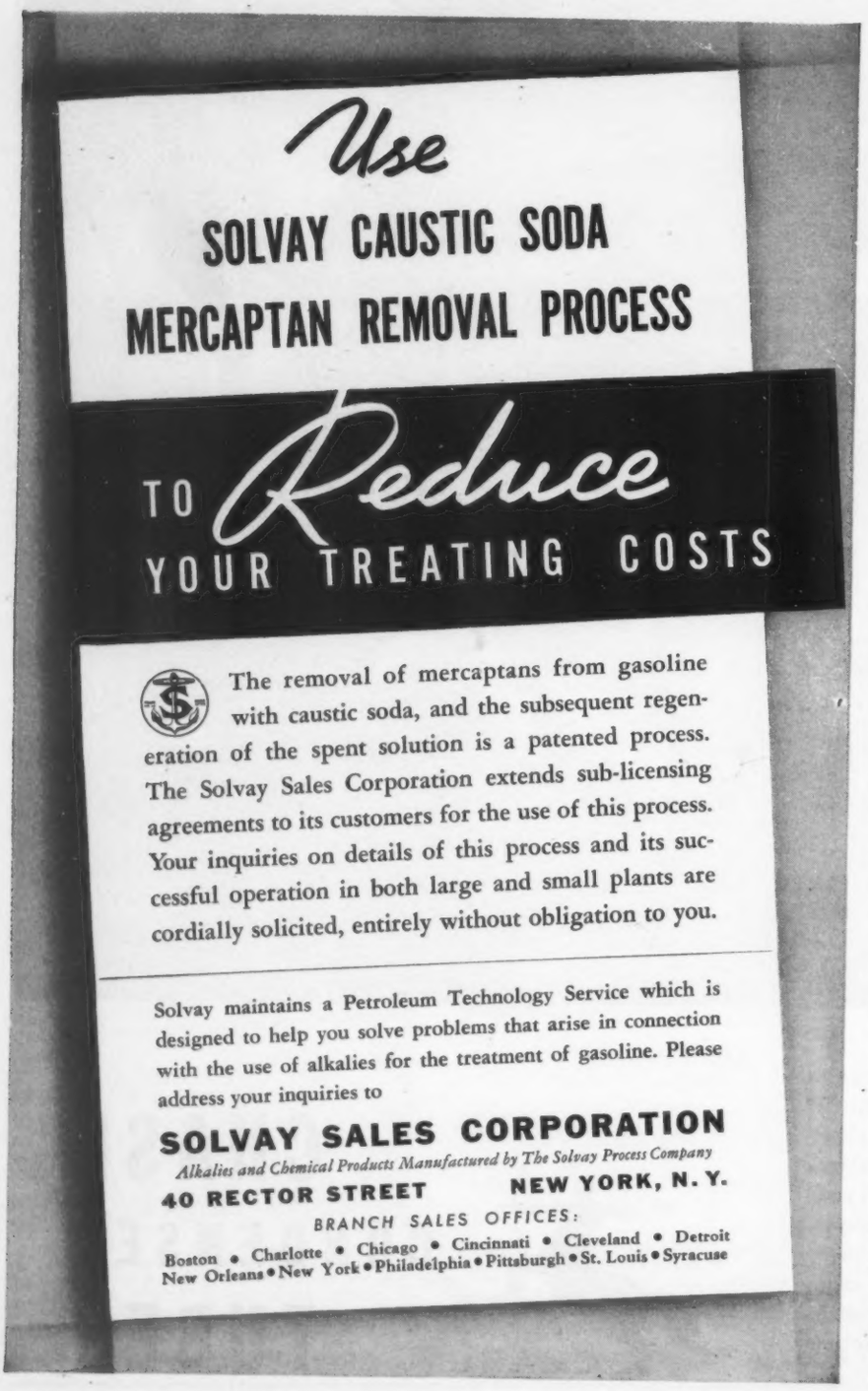
During most of this period S. W. Craig, now superintendent of the gasoline plant at Wasson, Texas, was superintendent for Tonkawa and Braman. During the last year the plants were under supervision of R. H. Medler.

In addition to the long period without an injury, chief benefit to the employes, $2800 was saved in direct accident expense. What the record means further comes from this part of the announcement from the company:

"The men have realized the benefits of happiness, comfort and continuous income with an actual tangible saving of about $1700 in wages which might have been lost had normal accident frequency prevailed."

This was the second such record within the organization, since the two Bryan plants near Skellytown, Texas, completed 10-year no-accident periods in April, 1940.

The 10 Shell Oil Company natural gasoline plants in the Mid-Continent area won first place in the National Safety Council contest in 1939 because of one full year without a disabling injury.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N.L.R.B. Decision Overruled

An order of the National Labor Relations Board to the effect that the federation of employes of the Baytown and Ingleside refining plants of Humble Oil & Refining Company be disbanded was reversed by decision of the United States Fifth Circuit Court of Appeals in New Orleans, June 24. The court ruled in favor of the board on the issue that the company desist from interfering with federation of employes.

Action of the labor board followed an investigation of charges by the Oil Workers International Union, Locals 316 and 333, to the effect that the company interferred with employes' organization. It was the decision of the appellate court that employes had the right to join whatever organization they preferred, provided the company did not interfere in the organization.

Carbon Black Output Up

Both production and consumption of carbon black set record totals in 1939. Figures released June 14 by the Bureau of Mines were that production in the United States was 525,166,000 pounds in 1939, 10 percent above 1938; sales for 1939 reached 560,533,000 pounds, an increase of 36 percent over 1938. Exports passed 200,000 pounds for the first time, while domestic sales were 47 percent higher than 1938 and 14 percent above the previous record in 1936. These consumption figures reduced stocks to 130,792,000 pounds at the end of 1939. Stocks were 166,159,000 pounds at the end of 1938.

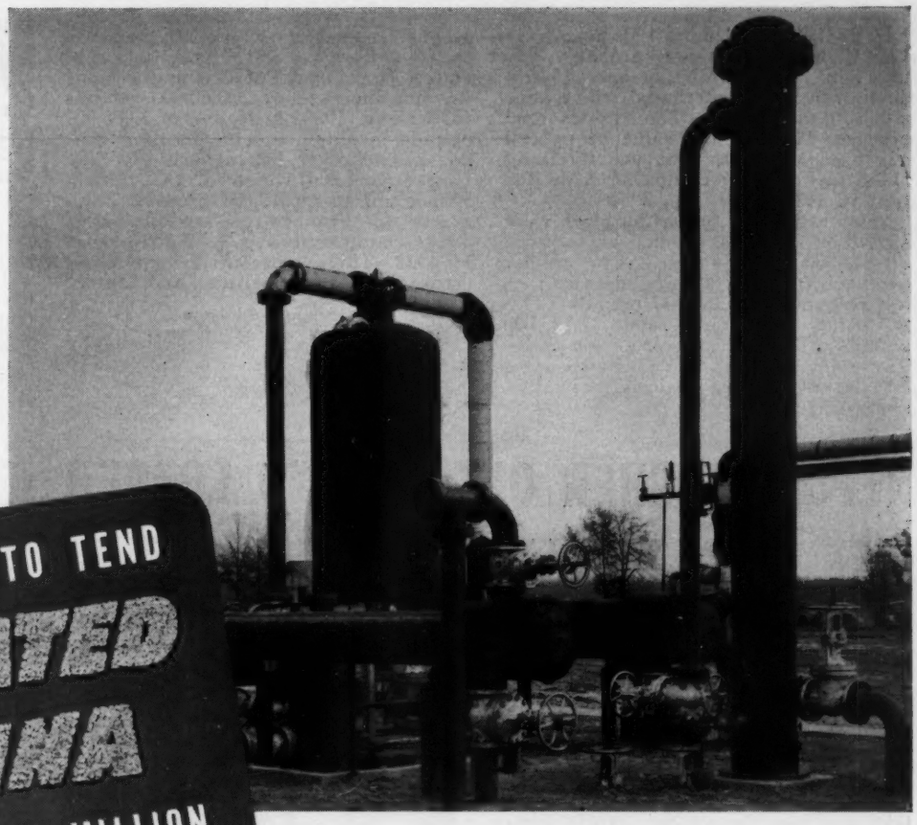
Although prices increased slightly toward the end of the year, income from finished material was classed as "distressingly low." The average for the year was 2.45 cents per pound, while the price in 1938 was 2.41 cents per pound. Export quotations, however, were lower in 1939, 4.36 cents per pound against 4.51 cents in the previous year.

Other details of the report are:

"Production in the Texas Panhandle was 410,130,000 pounds, 91 percent of the state total, compared with 92 percent in 1938. The output of the whole state reached a new peak, 453,174,000 pounds, 9 percent above that of 1938. Louisiana staged a come-back, rising to 51,734,000 pounds compared with 39,534,000 pounds in 1938. Kansas and Oklahoma continued at about 20 million pounds, while Wyoming, a producer since the first statistics (1919), dropped out of the list of producers.

"Two new plants were added to the operating list; eight were dismantled or shut down, making a total of 49 operated during the year compared with 55 in 1938.

"There were 347,270 million cubic feet of gas burned in the manufacture of carbon black in 1939, compared with 324,950 million in 1938. The average



In this illustration the tower at left contains Activated Alumina, the two horizontal cylinders serve for heating and cooling gas used to reactivate the unit; installed by Pittsburgh Lectrodryer Corporation.

NOBODY NEEDS TO TEND ACTIVATED ALUMINA WHILE IT DRIES 7 MILLION CU. FT. OF GAS DAILY

If you are looking for a better way to prevent regulator valve freeze-ups and internal corrosion of your lines and equipment, you'll be interested in this installation used for a repressuring operation in the Louden, Illinois field.

They are using Activated Alumina to dry 7,000,000 cubic feet of gas daily, at line pressure. This equipment requires only a few minutes of attention each day. It can easily be made fully automatic.

The same kind of equipment can catch moisture before it gets into your lines, and can save you money by removing the cause of corrosion and frozen valves. Activated Alumina is being used to handle such daily volumes as 21,500,000 cubic feet of gas at standard conditions. It is working continuously at line pressure drying gases to dew-points below minus 76° C. The method requires no solutions, evaporators, or moving parts.

Activated Alumina is being used also as a drying agent in thermal polymerization units, for protection of pipelines against hydrate formation, and as a catalyst and catalyst carrier. Send us a request on your letterhead for more information about its properties and uses. ALUMINUM COMPANY OF AMERICA, (*Sales Agent* for ALUMINUM ORE COMPANY) 1963 Gulf Building, Pittsburgh, Pennsylvania.

ACTIVATED ALUMINA

AN "ALORCO" ALORCO PRODUCT

yield per thousand cubic feet rose from 1.47 pounds in 1938 to 1.51 pounds in 1939. This increase was probably due to a gain in relative importance of production by "other methods" which have much higher yields than the channel process. The average value of natural gas used was 0.94 cent per thousand cubic feet in 1939 compared with 0.89 cent in 1938.

"Domestic sales of carbon black were 356,705,000 pounds, divided as follows: 316,621,000 pounds (89%) to rubber companies; 21,929,000 pounds (6%) to ink companies; 6,382,000 pounds (2%) to paint companies; and 11,773,000 pounds (3%) to miscellaneous users. These data indicate that all four classes of consumption maintained their relative positions in 1939.

"Exports were 203,828,000 pounds, according to data supplied by the Bureau of Foreign and Domestic Commerce, Department of Commerce. This was an increase of 35,860,000 pounds (21%) over 1938. A decline of 3,986,000 pounds in shipments to Germany was far outweighed by exports to the United Kingdom which increased about 50 percent to 66,215,000 pounds. Shipments to France rose to 29,391,000 pounds compared with 26,217,000 pounds in 1938. There were also notable increases in exports to Brazil and China."

Western States Gasoline Company has moved its offices to the Subway Terminal building, 417 South Hill Street, Los Angeles.

Hazard of Mercury Vapors

GROWING use of liquid mercury in analytical petroleum laboratories and its consequent hazard to health prompted a report of investigations, "Hazard of Mercury Vapor in Analytical Petroleum Laboratories, prepared by members of the staff of the experimental station of the United States Bureau of Mines at Bartlesville.

Two laboratories at the station were used and the amount of mercury in concentration in the air in the absence of ventilation was found to be as high as 7.38 milligrams per 10 cubic meters. This and other experiments brought this as part of the conclusion:

"The use of liquid mercury in analytical laboratories does not always result in the establishment of a definite health hazard because of the mercury vapors. However, such use does represent a constant potential hazard that may result in cases of chronic mercurialism by reason of poor housekeeping and inadequate year-round ventilation. Since mercury is volatile at temperatures as low as 8.5° F. some mercury vapor will be present in all enclosed or partly enclosed structures in which mercury is exposed to the air, unless operating conditions require subnormal temperature.

"Although no definite threshold value has been set for mercury vapor and volatile mercury compounds, chronic mercurialism has been occasioned by continued exposure to concentrations as low as 0.6 milligram of mercury vapor per 10 cubic meters of air. Test results of two petroleum laboratories discussed in this report show definitely that this figure may easily be exceeded except under optimum conditions when natural or inadequate mechanical ventilation are depended on to dissipate the vapors given off from exposed surfaces of liquid mercury."

Precautions and recommendations in handling mercury were taken from the General Electric Handbook GEQ-104 as follows:

The most important factors contributing to the prevention of mercury poisoning are good housekeeping and personal cleanliness of the operator.

Inasmuch as mercury evaporates at room temperature rapidly enough to create a dangerous concentration in room air (especially if the room be very warm), extreme care should be exercised to minimize spilling and to see that spilled mercury is cleaned up with water at once. Since mercury will not evaporate under water and water tends to keep down dusts which may contain mercury, copious amounts of water should be used at all times when cleaning up mercury. Mercury should also be kept covered with water when left standing in open vessels.

In all rooms where it is possible that mercury might be spilled, floors with a smooth hard finish, such as terrazzo, are necessary. These floors should be properly sloped toward a sump or catch basin to which mercury can be flushed or drained. To assist in the elimination of pools of mercury on the floor, steel pans of appreciable depth should be provided into which to drain mercury when emptying any small container.

* * * Board floors with cracks, or floors covered with any covering like

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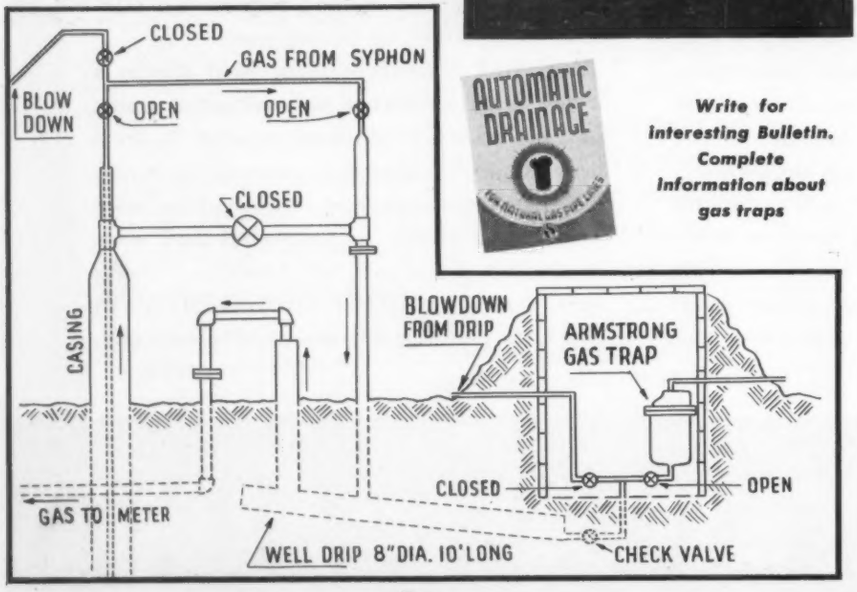

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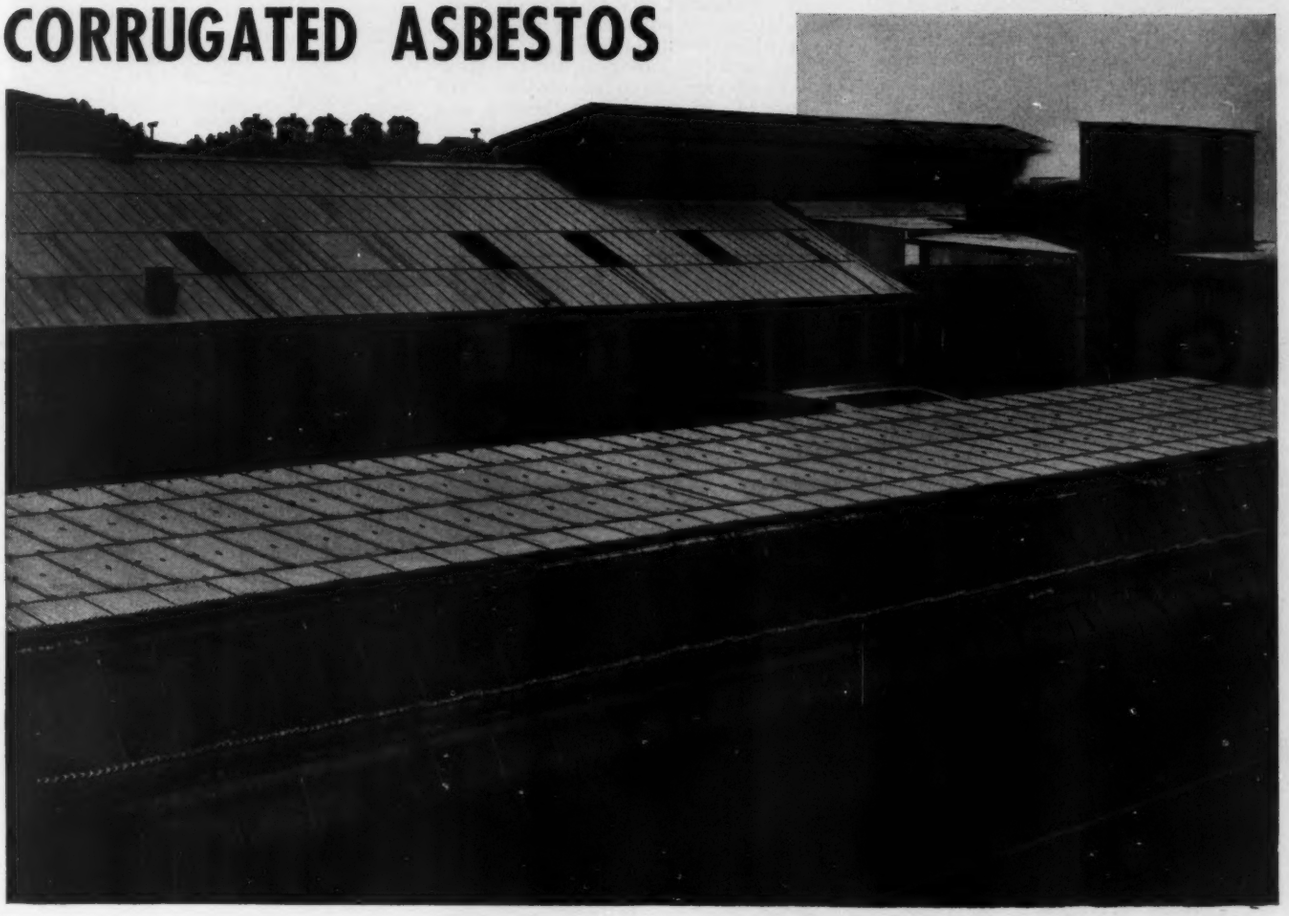

Buildings of the Hockensmith Wheel & Mine Car Co., Penn, Pa., roofed with Keasbey & Mattison "Century" Corrugated Asbestos. Truck Body Unit Building shown in foreground.

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loose linoleum, under which mercury can accumulate, are especially to be avoided. This is also true of rough or porous concrete, as concrete will absorb mercury much as a sponge absorbs water.

The primary requisite of a good wall for mercury rooms is smoothness. Ledges and large horizontal cracks in particular are to be avoided and the walls should be painted as smooth and glossy as possible or be made of steel or vitreous material.

Inasmuch as the lungs absorb mercury in dust or vapor form very readily, any room or building where mercury might be spilled or otherwise exposed to the air should be provided with adequate mechanical ventilation. This is especially true of rooms where experimental work is carried on with mercury boilers or mercury-arc rectifiers and all laboratories where mercury is used in such a manner that it can be scattered about or otherwise exposed to the air.

Small portable mercury detectors using sensitized paper ribbons are available and should be operated at all times while workmen are in the room. When mercury vapor is thus discovered in the air, steps should be taken at once to eliminate the source and to improve the air circulation; windows should be opened if this will definitely improve the ventilation. Careful attention must be given not only to the provision of an adequate supply of fresh air, but likewise to its distribution.

Specific Precautions

(Only those adaptable to laboratory workers have been quoted.)

1. Working places should be ventilated, preferably by mechanical means, so that there is always an abundant supply of fresh air.
2. A negative pressure should be maintained at all times in the furnaces of mercury boilers, stills, and similar equipment to prevent the escape of fumes or dust.
3. Mercury should be stored only in tight flasks or under water in a suitable flask.
4. Food should not be kept or eaten near mercury or in mercury workrooms; to eat near mercury is to risk eating mercury along with your food.
5. All applicants for employment in departments using mercury are to be given a special examination at the company hospital. The examining physician should be informed that the applicant contemplates work with mercury equipment.
6. Employes working with mercury should be given a physical examination every two or three months and before returning to work after lost-time illness. They should report to the company physician immediately if ill for any reason. This will make possible early treatment and permit the discovery and removal of any unknown dangerous condition before harm is done to others.
7. Spilled mercury is dangerous and spilling should be carefully avoided. Anyone spilling mercury should see that it is flooded with water and cleaned up at once. Pans containing water should be placed under all packing glands, valves, etc., which may leak mercury.
8. Never use an air hose to blow dirt or mercury off of the floor or mercury equipment. To do so is to stir up mercury, which will immediately be breathed and absorbed through the lungs. Mercury may be picked up by means of a strong suction through a metal nozzle not over ⅛ inch in diameter.
9. As personal cleanliness and personal hygiene are important factors in preventing poisoning by mercury, the following instructions should be given careful attention:
   (a) Wash your hands carefully before eating or handling anything that will be placed in the mouth.
   (b) Always rinse your mouth before taking a drink or eating.
   (c) Drink water and milk plentifully.
   (d) Never come to work without having eaten a substantial meal. With an empty stomach, conditions are more favorable for the absorption of mercury into the body.
   (e) There is danger in the handling and use of tobacco near mercury. Do not use it when on duty or carry it in your work clothes. Especially if you smoke a pipe or roll your own cigarettes, there is danger that mercury from your hands will get into your tobacco, where

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(f) Care of the teeth and gums is most important. They should be kept clean and healthy, and should be examined at least once every six months by a dentist, and his recommendations followed.

(g) If you feel at all sick, consult the company physician at once.

The use of reagents, such as hydrogen sulfide, both as a gas (12) and a solution (18), has proved successful in some instances in combating the hazard accompanying the exposure of liquid mercury in laboratories and workrooms. However, hydrogen sulfide is extremely toxic in itself.

▼ PLANT ACTIVITIES ▼

Largest Recycling Plant: Construction of the world's largest recycling plant for Cotton Valley field, Webster Parish, Louisiana, was announced in June. It will have capacity for 150,000,000 cubic feet of gas daily, and daily gasoline output of 10,000 barrels is calculated. The plant will be a cooperative venture with Ohio Oil Company, H. L. Hunt, Magnolia Petroleum Company, Oliphant Oil Company, North American Oil Company, United Gas Company and Stanolind Oil & Gas Company participating.

These concerns now have 81 distillate wells producing from the two lower marine sands. Immediately, 10 input wells will be added. The field covers 12,000 acres, and the plan contemplates additional drilling for producing the two sands over the area as well as repressuring the two formations.

The gasoline extraction and repressuring plant is estimated to cost $1,500,000. Additional wells will cost $100,000 each. First information to the effect that the project will involve an expenditure of $18,000,000 is thought to include cost of the 81 wells already drilled, since their cost will be pooled in the cooperative venture.

Derby Installs Sweetening Unit: Derby Oil Company, Wichita, has under construction a 2500-barrel Perco copper sweetening unit. It is the solid process type unit for the treatment of refinery straight run gasoline.

Increased Efficiency at Agua Dulce: Lockhart Oil Company's recycling plant near Corpus Christi, in the Agua Dulce gas-distillate field, has made a considerable improvement since its completion several months ago. Designed for a production of 25,000 gallons per day, the plant, employing high pressure absorption, is now manufacturing in excess of 35,000 gallons of distillate. Extraction efficiency is the highest of any reported results. Contributing to extraction efficiency is the reabsorption of vent tank vapors. The plant was designed by Petroleum Engineering, Inc., Tulsa, and is operating under a license of Distillate Engineering & Processes Company.

New Illinois Plant: Warren Petroleum Corporation, Tulsa, has announced plans for a plant for processing natural gasoline, propane and butane in the Salem-Lake Centralia field of Marion County, Illinois. The plant will take all gas with more than three-fourths of a gallon gasoline per 1000 cubic feet.

Recycling at Joaquin: Paul H. Hewitt, Longview, has announced plans for a $250,000 recycling plant of 50,000-cubic-foot capacity in the Joaquin area of Shelby County. A like amount is to be spent in developing the gas reserve in the Rodessa section of the Glen Rose.

Improvements for Two Plants: Bell Oil & Gas Company has announced additions and improvements to its refinery at Grandfield, southern Oklahoma, and also to the Ben Franklin refinery at Ardmore, Oklahoma.

The Grandfield plant has completed revamping its straight-run distillation apparatus, including enlargements of pipe stills and installation of new burners to increase capacity of number one still to 4000 barrels per day. New pumps have also been added. A new firing system has been installed on the Dubbs cracking unit, and the vapor recovery system has been improved.

At the Ben Franklin plant, a complete new treating system has been installed to improve gasoline quality and reduce treating costs.

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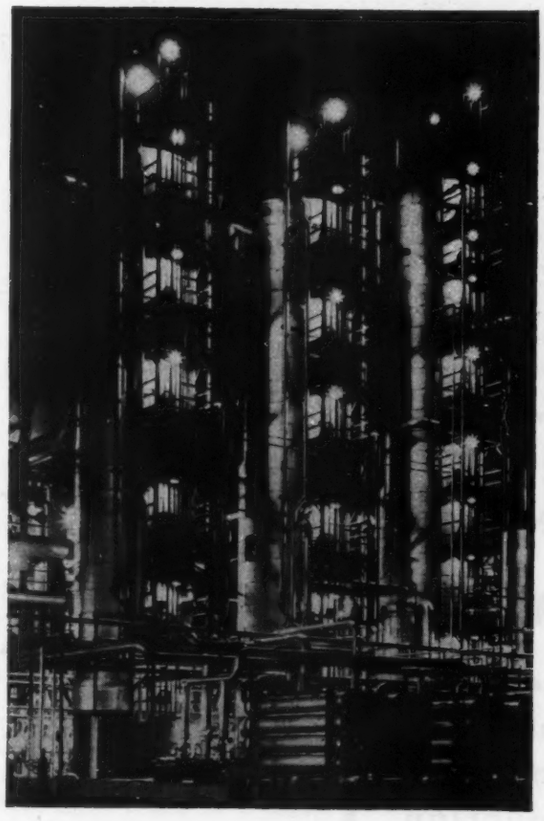

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SCIENCE AND TECHNOLOGY

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by

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under the supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

Phase Equilibria in Hydrocarbon Systems, B. H. SAGE, H. M. LAVENDER, AND W. N. LACEY, *Ind. & Eng. Chem.* **32** (1940) pp. 743-7.

The volumetric behavior of six mixtures of methane and decane was determined at five temperatures between 70° F. and 250° F. The experimental work included measurements in the condensed liquid and two-phase regions at pressures as high as 4500 pounds per square inch absolute. From these basic data the partial volumetric behavior of methane and decane was calculated for the liquid phase. The experimental procedure is described, and the results are presented in detail in tabular and graphical form.

The Thermodynamics of n-Heptane and 2, 2, 4-Trimethylpentane, Including Heat Capacities, Heats of Fusion and Vaporization and Entropies, K. S. PITZER, *Jour. Am. Chem. Soc.* **62** (1940) pp. 1224-7.

Extending work previously done on the butanes and tetramethylmethane the author studied the thermal behavior of n-heptane and of 2,2,4-trimethylpentane from 15 to 423° K. Heat capacities of the solid, liquid or gas are given. The values of the heats of fusion and vaporization obtained are: n-heptane, 3355.8 $\pm$ 4 and 7660 $\pm$ 20; 2,2,4-trimethylpentane, 2201.6 $\pm$ 2, 7410 $\pm$ 20 calories per mole. The entropies were calculated for the liquid at 298.1° K. and for the gas at the boiling point, and are, respectively: n-heptane 78.60 $\pm$ 0.2 and 111.77 $\pm$ 0.3; 2,2,4-trimethylpentane 78.40 $\pm$ 0.2 and 112.05 $\pm$ 0.3.

Resonance Method for Measuring the Ratio of the Specific Heats of a Gas, C_p/C_v, ARTHUR L. CLARK AND L. KATZ, *Can. J. Res.* **18** (1940) pp. 23-38.

The authors describe and give the theory of a modification of Assmann's method for determining $\gamma = C_p/C_v$, the ratio of the specific heats of a gas. The gas is enclosed in two chambers formed by the ends of a cylinder with a steel piston in the middle. The piston is caused to oscillate by an alternating current applied in coils outside the cylinder. The gas is thus subjected to alternate compression and rarefaction. The system has a natural frequency depending on the constants of the apparatus and the value of γ for the gas. The frequency of the alternating current is varied, the amplitude of the motion of the piston is observed, and the frequency of resonance measured. From this frequency and the constants of the apparatus the value of γ is found. The results are both accurate and reproducible.

Ultraviolet Spectrum of Paraffins and Petrolatums, E. VELLINGER AND B. THOMAS, *Compt. rend.* **210** (1940) pp. 296-7; *cf. C.A.* **34,** p. 1467.

The ultraviolet ($\lambda\lambda$2000-4000A) spectra of paraffins and cyclanes show no characteristic differences, but crystallized paraffin extracted from petroleum shows an absorption some 100 times as great as that of a paraffin oil from which all aromatic nuclei have been removed by fuming sulfuric acid. The solid residue that remains when petrolatum is fractionated under a cathodic vacuum is also highly absorbent. The authors conclude that this is caused by the presence of highly substituted aromatic hydrocarbons in addition to the two paraffins and cyclanes.

The Dependence of Viscosity of Liquids on Constitution, A. H. NISSAN, L. V. W. CLARK, AND A. W. NASH, *Jour. Inst. Petr.* **26** (1940) pp. 155-211.

This is a paper of 55 pages and 11 pages of discussion on the relationship of viscosity to the constitution of liquids. A bibliography of 97 references is included. In reviewing the literature the authors considered certain points to be universally accepted and took these as the basis of their work. An ultimate flowing unit of liquid was assumed to move in jumpy fashion and energy to be consumed in giving the ultimate unit the necessary increment to enable it to jump. This energy is represented by Q in the equation $n = Ae^{Q/RT}$. The connection between Q and the boiling point T_B was found to be more fundamental than the relationship between Q and the freezing point. The ratio of molal latent heat of vaporization to the corresponding heat of viscosity was found to be a constant, n, characteristic of the liquid; n appeared to afford the key to the study of viscosity as it is affected by constitution. A formula was found connecting the molal latent heat of vaporization and the melting point of monoatomic liquids. The authors concluded that the three states of matter, solid, liquid, and gaseous, can be defined by a continuous series of changes with regard to the laws of viscous flow. The relationship between viscosity and vapor pressure was studied in detail and the conclusion reached that both phenomena are functions of essentially the same variables. The value of n for n-paraffin was proved to be fractional and of the value, 4.13. Trouton's rule combined with Clausius Clapeyron's equation indicated that log n plotted against T/T_B for the n-paraffins yielded a single curve. This was called the specific viscosity curve. By a change in the temperature scale it was possible to plot log n against T/T_B on such a scale so that a straight line was obtained. It was then proved that any liquid that yielded a straight line on these charts followed the same law as the n-paraffins with regard to change of n with temperature. All of the 137 liquids tested yielded straight lines. It was thereby concluded that all liquids, associated or unassociated, possess only one

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formula connecting n and T. It was found that the heat of activation of viscosity was a function of temperature even for the n-paraffins. Thus the chief distinction between associated and unassociated liquids from the point of view of viscosity disappears in principle. In studying liquids it was found that the chief variable that characterizes the specific viscosity curve was the molecular shape. Molecular shape was discussed and postulated as the shape of the equipotential surfaces surrounding the molecule. When the molecular shape was nearly symmetrically spheroidal the specific viscosity curve was found to lie to the right of curve for a liquid of which the shape of the equipotential surface was less spheroidal. Dipole moments were found to be of secondary importance. The nature of the atoms of the molecule were shown to be immaterial; once a certain shape has been attained the specific viscosity curve assumes a position on the chart independent of the nature of the molecule. Viscosity index was studied. The remarkable conclusion was reached that a liquid composed entirely of cyclic structure would yield a high viscosity index if the rings were all joined end-on so that the molecule was elongated in shape. It has been shown that one formula must exist for all flowing matter with certain terms predominating, depending on the state of matter and the nature of flow; for example, the term defining fall of viscosity with rise of temperature predominates in the order: gases at low pressure, gases at high pressure, helium, metallic elements, non-metallic elements, unassociated liquids, associated liquids, non-Newtonian liquids, plastics, and crystals.

Viscosity of Gases and Vapors at High Pressures. E. W. COMINGS AND R. S. EGLY, *Ind. & Eng. Chem.* **32** (1940) pp. 714-8.

The rapid development of high-pressure processes has increased the need for methods of equipment design that are applicable to any fluid. Although considerable information is available as to the effect of pressure on the density of gases and vapors, there is need for information on viscosity, thermal conductivity, and diffusivity. A graphical method, based on the concept of corresponding states, is described for predicting the viscosity of pure gases and vapors at high pressures when the viscosity at atmospheric pressure and the critical temperature and pressure are known. Calculations made by the method are compared with published viscosity data on 7 gases and vapors. At pressures and temperatures above the critical, the predicted viscosities differ from those measured experimentally by less than 20 percent. The agreement of the predicted viscosities with the experimental is as close as the agreement between the experimental results of different investigators on single compounds at all pressures and temperatures reported.

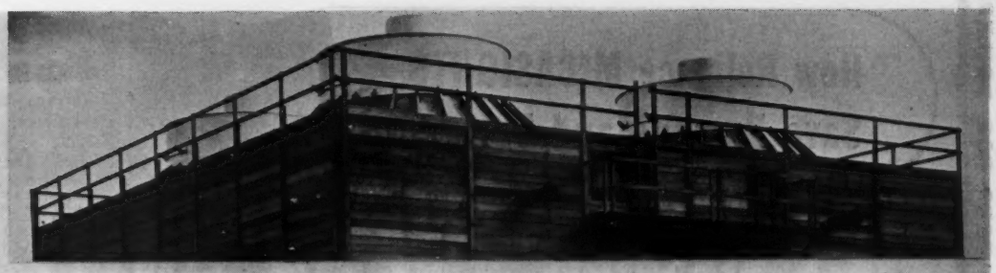
A Study of the Flow or Air in Tubes in the Pressure Range 1-300 Atmospheres, R. W. MOULTON AND W. L. BEUSCHLEIN, *Trans. Am. Inst. Chem. Engrs.* **36** (1940) pp. 113-33.

The viscosity of air was determined at 30° C. for the pressure range 1 to 300 atmospheres. The value of the friction factor "f" was determined for air flowing in turbulence through 3 copper tubes for the pressure range 1 to 300 atmospheres. The increase of viscosity of air with increase in pressure is greater than previously reported at pressures up to 200 atmospheres. Between 200 and 300 atmospheres it increases less rapidly, and approaches a value where the viscosity will be independent of the pressure. The magnitude of the value of "f" is independent of pressure for a particular Reynold's number over the range 1 to 300 atmospheres. The variation of "f" with Reynold's number for air, over the pressure range investigated, follows closely to the accepted values for gases and liquids under normal pressure in smooth tubes. In both streamline and turbulent flow of air, it appears that the observed pressure drop is not uniquely determined, but is capable of existing between a small range of values for a given set of operating conditions.

Chemical Compositions And Reactions

A Comparison of the Chemical Characteristics of Crude Oils Produced in the Old and New Illinois Fields, O. W. REES AND P. W. HENLINE, *Trans. Ill. State Acad. Sc.* **32** (1939) pp. 122-3.

The crude oils produced from the newer fields in Illinois show higher gravities, lower viscosities, higher yields of gasoline, lower boiling points and lower average molecular weights than those from the older Illinois fields. The content of sulfur in the newer oils is somewhat higher than in the older oils.



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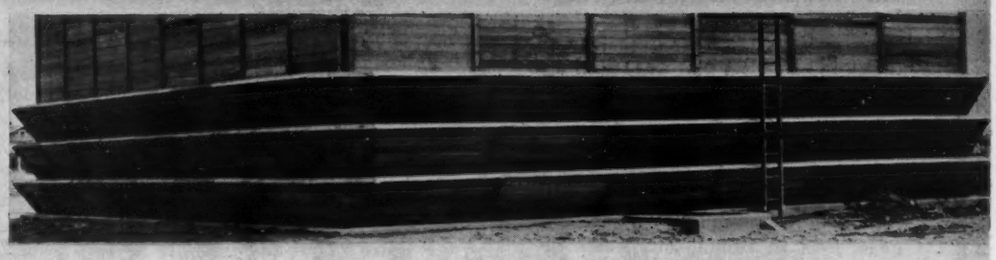

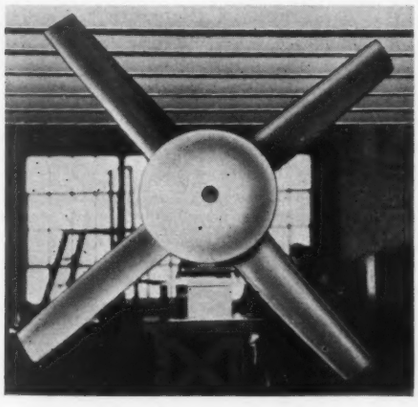

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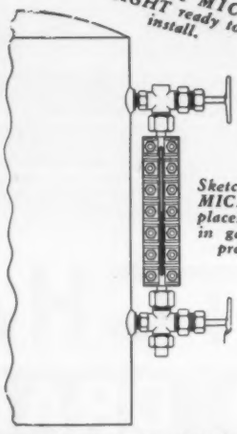

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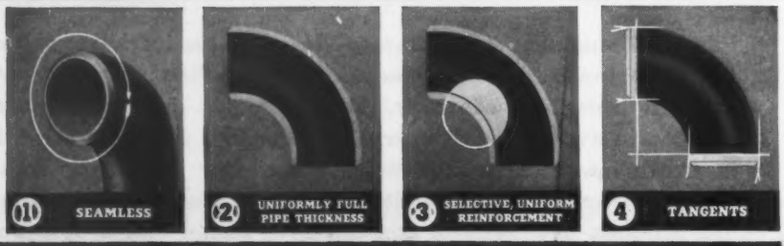

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Characterization factors of the more recently produced oils are higher, indicating that the newer oils are more paraffinic than those formerly produced.

Separation and Characterization of Petroleum Acids, H. G. SCHUTZE, B. SHIVE, AND H. L. LOCHTE, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 262-6.

The petroleum Acids contained in the alkali wash obtained in the refining of light burner oil at the Baytown Refinery of the Humble Oil and Refining Company were investigated. The usual procedure for the separation of the acids is described, as well as many special procedures used by the authors. The necessity for the use of a combination of constants to characterize the various cuts obtained is noted. Among the acidic substances identified were phenol, n-valeric, n-butyric, dimethylmaleic, n-octanoic, and solid hexa-hydro-p-toluic acids. The methods used are outlined in considerable detail and typical data obtained are presented in tabular and graphical form.

Petroleum Bases. I. Reactions of 2, 3, 8-Trimethylquinoline, A. BURGER AND L. R. MODLIN, JR., *Jour. Am. Chem. Soc.* **62** (1940) pp. 1079-83.

Several of the reactions of the kerosene base, 2, 3, 8-trimethylquinoline, were studied. These reactions were principally concerned with the 2 and 5 positions of the quinoline system. The derivatives obtained by means of these reactions will serve as starting materials in the syntheses of several compounds containing pharmacologically interesting groups.

Physical Properties and Chemical Constitution. IV. Methylcyclohexane and the Multiplanar Structure of Methylcyclohexane, D. M. COWAN, G. H. JEFFERY, AND A. I. VOGEL, *J. Chem. Soc.* Dec., 1939, pp. 1862-5.

The authors present further evidence for the existence of B and B′ forms of methylcyclohexane. The A forms have been shown to be impure B′ forms, but the possibility of a third isomeride is suggested. The results support the view that methylcyclohexane ring exists in multiplanar forms.

The Action of Elementary Fluorine upon Organic Compounds. VIII. The Influence of Dilution on the Vapor Phase Fluorination of Ethane, D. S. YOUNG, N. FUKUHARA AND L. A. BIGELOW, *Jour. Am. Chem. Soc.* **62** (1940) pp. 1171-3.

A study was made of the effect of nitrogen dilution on the vapor-phase fluorination of ethane. It was found that a mixture of partially fluorinated ethanes can be thus obtained in excellent yield under proper reaction conditions. Pentafluorethane CF_3CHF_2, symtetrafluoroethane CHF_2CHF_2 and 1, 1, 2-trifluoroethane CHF_2CH_2F have been isolated from the reaction products that boil above —78° C. The first-mentioned of these is a new compound, the others have not been previously prepared by direct fluorination.

Determination of Methylpropene by Means of a Modified Deniges Reagent, A. NEWTON AND E. J. BUCKLER, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 251-4.

Two methods are at present available for the determination of methylpropene, one using sulfuric acid and the other hydrogen chloride. Little attention has been paid to Deniges reagent, the use of which depends on the formation of a precipitate by methyl propene from solutions of mercuric nitrate. The determination of methylpropene by means of Deniges reagent is complicated by the solubility of the precipitate in nitric acid and the change in weight and composition of the precipitate on washing with water. The first source of error can be eliminated by using a neutralized reagent. The second can be avoided by using as the measure of methylpropene absorbed, not the weight of the precipitate but the weight of mercury in the precipitate. The weight of mercury is constant under the conditions of the determination and amounts to seven atoms for each molecule of methylpropene used. With these modifications the method is accurate and reasonably rapid.

Manufacture: Processes and Plant

Petroleum Refining, W. MILLER, *Mining and Met.* **21** (1940) pp. 51-3.

The author reviews the progress of petroleum refining during the last year. The average octane number of so-called "house-brand" gasoline increased 2 points during 1939. Catalytic cracking and catalytic reforming were developments of importance. Other important

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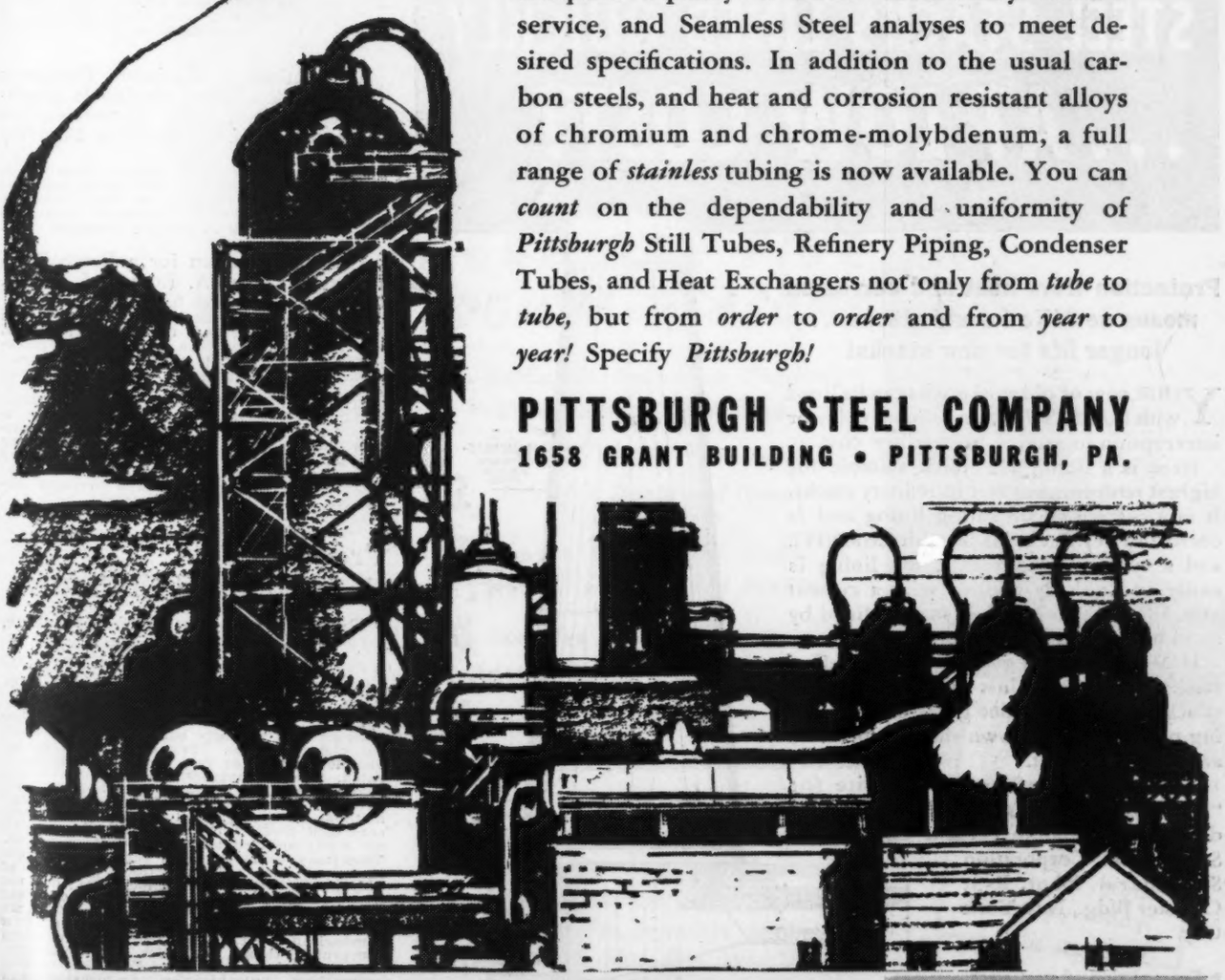

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contributions in the production of high octane fuels include: increased capacity of thermal reforming plants, with improved costs because of better yields and octane number through use in conjunction with catalytic polymerization, the more widespread use of catalytic and thermal polymerization, the increasing use of alkylation processes, the wider use of improved desulfurization methods, the application of close fractionation to separation of pure hydrocarbons with high octane values. Catalytic polymerization lends itself well to combination with reforming, and adds several percent to the liquid yield while increasing the octane gain. It is not applicable to catalytic reforming because of the lean gas produced by the latter process. Use of petroleum, or products therefrom, as a raw material for chemical synthesis increased considerably during 1939.

Service and Life of Nonferrous Tubes in Petroleum Refining, E. S. DIXON, *A.S.T.M. Bull. No. 102* (1940) pp. 21-6.

Brasses such as Muntz metal and admiralty metal often fail in service because of dezincification. The alloy goes into solution and copper is redeposited. This is readily corroded by the sulfides in the oil. In order to avoid dezincification red brass is frequently used. This alloy fails from water pitting and its high copper content (85%) causes it to be easily corroded by the sulfides in the distillate. The addition of arsenic reduces dezincification; however, such alloys crack too easily. Antimony and phosphorous are said to reduce dezincification corrosion. The same material frequently acts differently at different times because of variable factors such as nature of cooling water or temperature. Corrosion is most rapid where vapors are condensed to liquids. On the oil side, corrosion may be acid corrosion, which can be identified by the etched appearance or green color; sulfide corrosion as indicated by black copper sulfide scale; ammonia corrosion, as indicated by deep blue deposits. Erosion is frequently a factor in tube failure. Among the alloys tested for tubing 70-30 copper-nickel has shown good results, but its cost is twice that of admiralty metal. Copper-lined admiralty metal and copper-lined steel appear to be satisfactory. Monel tubes are undergoing tests. Aluminum brass tubes (76 Cu, 22 Zn, 2 Al) have shown no failures after service for more than a year. Poor success has been had in the use of stainless steel tubes in exchangers and condensers. Some effort has been made to reduce water corrosion by removing oxygen from the cooling water or by the addition of chemical inhibitors such as chromate. Electrolytic corrosion can be prevented by keeping the metal parts at a negative potential with respect to an anode in contact with water; this can be done by using a d.-c. generator and a steel anode. Results of such tests will be published at a later date.

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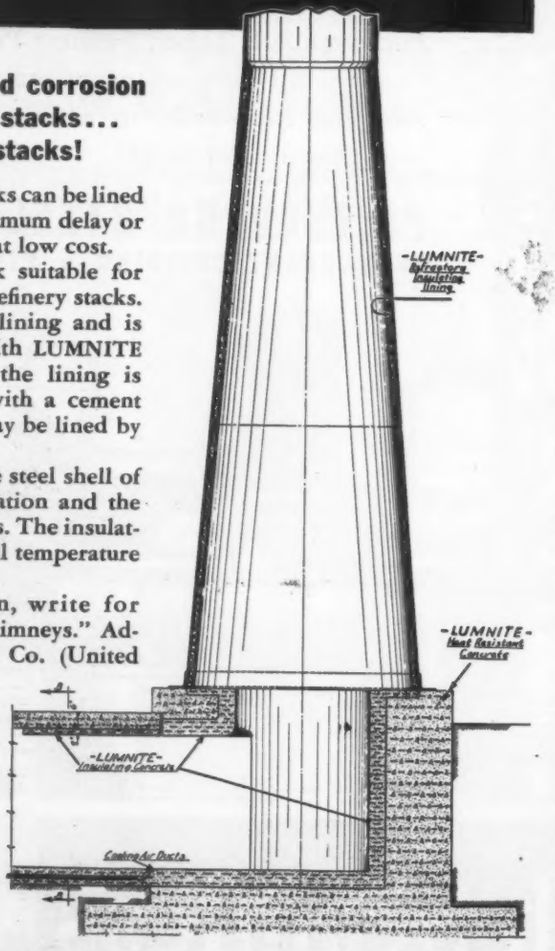

▶ Cross-section of steel stack, showing Lumnite protective lining, and a duct installation below built of Lumnite heat-resistant concrete lined with Lumnite insulating concrete.

LUMNITE FOR REFRACTORY CONCRETE

Sharpness of Separation in Batch Fractionation, A. ROSE AND L. M. WELSHANS, *Ind. & Eng. Chem.* **32** (1940) pp. 668-72.

The increasing importance of batch fractionation processes in manufacture and in control, analysis, and research, is noted. In the series of three papers the theory of batch fractionation is slated in such manner as to make possible the prediction of the maximum sharpness of separation with a given column and solution to be separated or the minimum efficiency required for a specified separation. It is pointed out that theory indicates the general nature of the effect of vapor pressure ratio, holdup, reflux ratio, and overall fractionating factor on the sharpness of separation in batch fractionation. The chief importance of the equations presented in the first article lies in establishing the limiting values of maximum sharpness of separation and minimum plates required and in indicating the general nature and importance of some of the relationships involved in batch fractionation.

Calculation of Maximum Sharpness of Separation When Holdup Is Appreciable, A. ROSE, L. M. WELSHANS, AND H. H. LONG, *Ind. & Eng. Chem.* **32** (1940) pp. 673-5.

This is the second of a series of three papers on batch fractionation, and deals with the derivation of an equation for calculating the maximum sharpness of separation when the holdup of the column has any assigned value.

General Equation for a Batch Fractionation Curve, A. ROSE, *Ind. & Eng. Chem.* **32** (1940) pp. 675-6.

This paper is the third of a series on batch fractionation. The first two papers presented the development of an equation for calculating the distillation curves for batch fractionation if simplifying assumptions were used. This paper indicates the method of derivation and the form of the equation obtained when no simplifying assumption is involved in the derivation. The resulting equation can be used for the calculation of any specific distillation curve, but it is necessary to use a graphical method similar to that described in connection with a previous discussion of the Rayleigh equation.

Products: Properties and Utilization

Rubberlike Properties of Polybutene, W. J. SPARKS, I. E. LIGHTBOWN, L. B. TURNER, P. K. FROLICH, AND C. A. KLEBSATTEL, *Ind. & Eng. Chem.* **32** (1940) pp. 731-6.

Polymers prepared from the butenes at low temperatures resemble rubber in many physical characteristics. They differ from rubber chemically in that they are essentially saturated. The polybutenes, which are available commercially as Vistanex polybutene, have not yet been vulcanized by conventional methods. They are inert toward ozone and concentrated acids. When stretched they exhibit an X-ray pattern similar to that of rubber. They may be mixed with rubber to improve its ozone and acid resistance. Spheres of polybutene at room temperature do not bounce, but at 212° F. rebound is close to that of rubber. Because rubber and polybutene are physically similar but chemically dissimilar, a comparison of the two permits conclusions concerning those properties for which unsaturation alone is responsible. Based on this comparison, vulcanization, ozonization, and oxidation are caused by unsaturation. Tensile strength, elasticity, rebound, X-ray structure electrical properties, elastic memoray, fractional solubility, and mechanical orientation are physical properties of the higher molecular weight polybutenes that closely resemble those of rubber and therefore appear to be largely independent of orientation caused by carbon-double bond-carbon configuration within the molecule.

Cutting Fluids, J. GESCHELIN, *Automotive Ind.* **81** (1939) p. 424.

An Independent Research Committee on cutting fluids has been formed to study the use of cutting oils and to give reports of use to production men and other users. Simplification can be achieved by limiting the number

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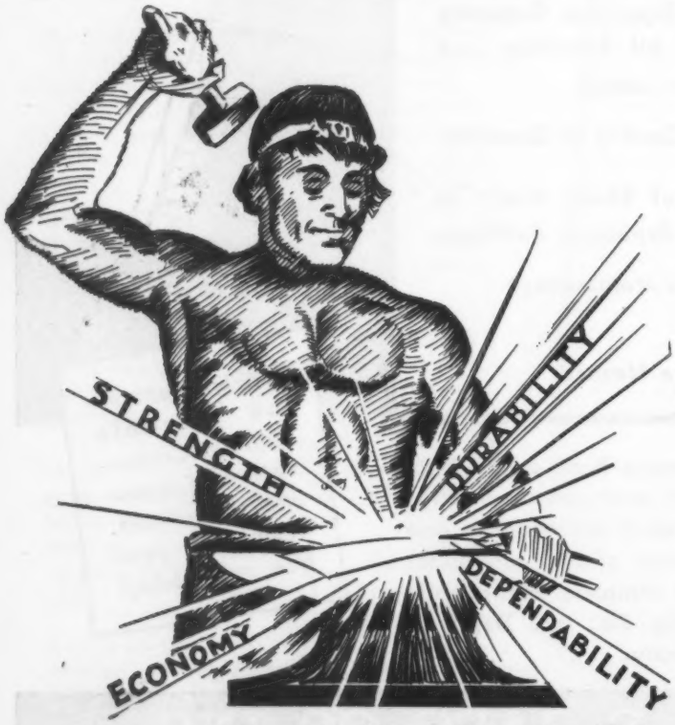

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of types to a minimum. An example is that of the Spicer Company, that uses only one grade of soluble and neat cutting-oil, with the exception of a special oil for the Gleasons. Central supply systems aid in this simplification, but if fine grinding is to be done, filters may be necessary. An outline is given of the general requirements of cutting fluids and of the types available. New developments in the way of sulphurized soluble oils are mentioned. The elimination of occupational diseases through keeping the cutting-fluid clean and the use of suitable antiseptic is stressed. A bibliography on cutting-fluids is included, as well as the names of the chief suppliers in America and the grades and types that they market.

Utilization of Mineral Oils for the Lubrication of Aeroplane Engines, E. THOMAS, *Bull. Ass. Franc. Tech. Petrol.* (1940) p. 29.

Although castor oil has been largely replaced by mineral oils because of its tendency to gum, it is still used to some extent on account of its excellent lubricating properties. The instability of castor oil has led to researches for a stabilized oil, but these have not resulted in a solution of the problem. The difficulties in manufacturing a satisfactory mineral aviation oil are great, and it is not to be thought that solvent extraction is a complete solution of the problem. In describing the required characteristics of mineral oils, the French specification, including the Dixmiar, Damian oxidation test, is mentioned. Curves are given that show the increase in viscosity, carbon residue, and insoluble substances in petroleum ether found in a 40-hour test of a 450 horsepower engine with and without changes of oil at intervals. A comparison is made of these results with those obtained in accordance with the air specification 1093 oxidation test. The deposits in the engine may be formed from the burning of oil in hot places or from incomplete combustion of the fuel. These deposits are suspended in the oil and are deposited in various places. Tests of carbonization in the absence of air by the Damian method prove that insolubles in $CHCl_3$ do not begin to form until a temperature of 340° C. is reached; i.e., the temperature at which oils begin to crack. Bearing corrosion troubles can be remedied by suitable choice of bearing metals, improved cooling of the oil, and the use of corrosion inhibitors. The author concludes that the task of the oil refiner is indeed difficult.

Hypoid Lubricants for Truck Axles, ANON., *Automotive Ind.* **82** (1940) p. 74.

It has been found that some types of hypoid lubricant are unsatisfactory at low speeds and heavy loads. Wear tests on the Almen machine differentiate between the so-called active and mild E.P. lubricants, the former giving a much higher temperature and rate of wear. The Chrysler Corporation now uses two classifications for hypoid lubricants, truck duty, and passenger-car duty. An outline of the testing procedure used by this corporation is given, and it is concluded that two sets of hypoid lubricants will come into general use: a truck duty type, a product that is not active to copper, and the generally accepted active passenger-car lubricant.

A Note On the Measurement of Flow Properties of Asphalts by the Penetrometer, C. C. MILL AND V. G. W. HARRISON, *Jour. Soc. of Chem. Ind.* **59** (1940) pp. 66-7.

In a recent paper the use of the penetrometer for measuring the viscous and plastic flow properties, thixotropy, and elasticity of bitumens was described by C. Mack. An equation was given that expresses the depth of penetration as a function of time, and attempts to show that the constant c of this equation gives a numerical measure of the flow properties of these materials. The authors of the present paper believe that they show that the reasoning in Mack's paper was mathematically unsound and that the penetrometer equations are less simple than would appear from his paper.

An Improved Mobilometer, K. C. COMBES, C. S. FORD, AND W. S. SCHAER, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 285-7.

A need has long been felt for an instrument or a method for the determination and expression of the consistency of fluid and semi-fluid greases that are too mobile to be tested with the A.S.T.M. penetrometer. This latter instrument gives satisfactory results for the solid or heavier types of greases, but with soft greases having penetrations higher than 360 the results are usually erratic. Viscometers such as the Saybolt are not suitable for testing these products because the products are not true liquid and change their characteristics when heated. The Gardner mobilometer, which is a special type of falling-weight viscometer, is reasonably satisfactory for determining the consistency of fluid and semi-fluid greases, but has a number of defects that have been corrected in a new and improved instrument designated as the S.I.L. mobilometer. This instrument is described, and typical results are given.

Supercharging. Because certain problems of engine design may become much more serious with continued increases in the compression ratios of some types of engines, and because supercharging is much more effective than high compression in the utilization of fuel anti-knock value to produce increased power, a rather widespread application of superchargers to future production engines may develop. It is possible that the relative performance of different types of high anti-knock fuels in supercharged engines will differ considerably from their relative performance in unsupercharged engines of high compression ratio. Therefore, experimental new fuels should be tested in supercharged engines as well as in high compression engines if their full potentialities and limitations are to be determined.

Fluid Drives. The use of fluid couplings between engine and transmission can offset, to a marked extent, the demands of intake manifolds which do not uniformly distribute fuel-air mixtures to individual cylinders. Without fluid drives, acceleration from low speeds requires that the engine operate for substantial periods at wide-open throttle in the speed range where poor distribution has its most adverse effect. However, with the fluid drive, engine speed is much higher during acceleration from low car speeds, and as a result, distribution of fuel-air mixtures to individual cylinders is materially improved during this type of full-throttle acceleration.

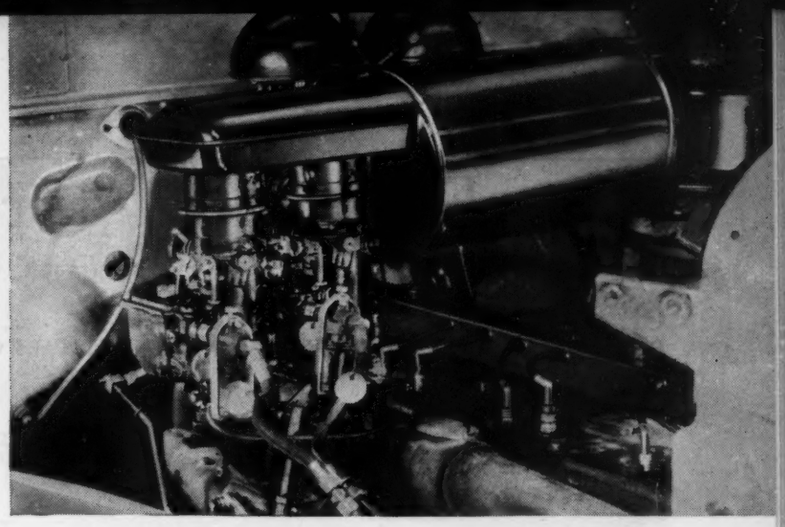
Pre-ignition. Unfortunately, some types of hydrocarbons which have high anti-knock value are apt to pre-ignite when subjected to high temperatures and pressures. Therefore, the fuels of the future must also be capable of withstanding, without pre-ignition, the severe conditions under which they will be burned in more efficient engines.

No limit to the extent to which increased fuel anti-knock value can be utilized to increase power and economy has yet been found. This is a consideration which the refiner who is preparing for development over a long range should keep in mind.

While new refining processes may produce fuels which in themselves have anti-knock values that are very high relative to octane numbers of present commercial fuels, fuel standards are not fixed and octane numbers which seem "high" today will be exceeded in the future. Therefore refining processes which produce fuels having both high anti-knock value *and* high lead susceptibility offer the greatest possibilities for future development.

* * *

Since the improvement of fuels and the development of engines are but phases of a single problem, we of the Ethyl Gasoline Corporation, through our Research Laboratories in Detroit and San Bernardino, are engaged in joint programs with many technical organizations in *both* the automotive and petroleum industries. We welcome opportunities to cooperate with the refiner to produce the most satisfactory and economical fuels for tomorrow's engines, and with the engine designer to make the best possible use of tomorrow's fuels. And through our staff of field engineers we are helping the users of engines and fuels in the practical application of laboratory findings. Ethyl Gasoline Corporation, Chrysler Building, New York, N. Y.



TWO-CARBURETOR ASSEMBLY above, together with dual fuel tanks, lines and pumps, permits the supply of one fuel to one cylinder group and another fuel to the other cylinder group of a single engine, for simultaneous comparison of the effects of different fuel characteristics on the endurance of engine parts.

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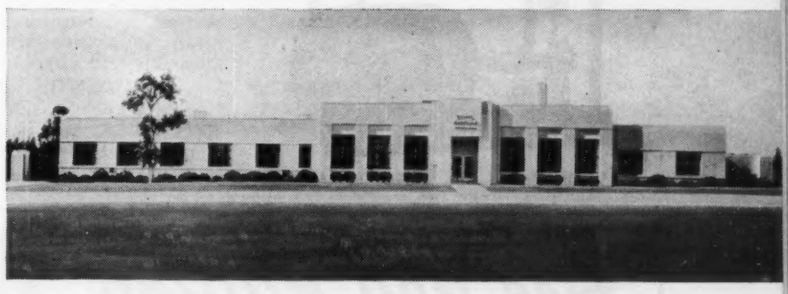
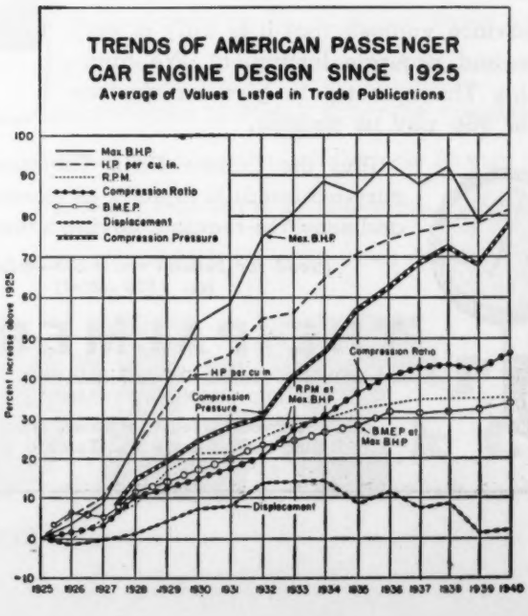
Here are some of the lines of research in which the Ethyl Research Laboratories are now engaged:

Anti-knock tests on new fuels ★ Supercharging and super high compression ★ Studies of improved ceramics and metal alloys ★ Pre-ignition ★ Effects of sulphur ★ Instrumentation ★ Effect of volatility on anti-knock value ★ Effect of supercharging and increased compression on power and economy of commercial vehicles and farm tractors ★ Study of the relation of lubrication to fuel and engine development.



THE SAN BERNARDINO LABORATORY of the Ethyl Gasoline Corporation specializes in road testing. Its location was selected because within a few miles can be found practically every type of road, climate and altitude condition.



THE TREND of the American car engine has been toward efficiency more than size. Continued cooperation of petroleum and automotive technologists is essential in the extension of this trend for the most effective development of transportation in the future.

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A new oil pressure unit designed for circulating lubricating oil at a uniform pressure through lantern glands of stuffing boxes, through large bearings, and for supplying oil to hydraulic equipment, heat-treating systems or where there is the problem of circulating or supplying oil at a uniform pressure, has been announced by Duralmetallic Corporation, 2104 Factory Street, Kalamazoo, Michigan.

The unit features a manual-type regulator to provide circulation up to 1000 pounds, a cooling coil of seamless copper tubing, an oil filter, pressure pump, explosion-proof electric motor, cast iron base, vapor-proof lid, oil tank vent, oil level gauge and pressure gauge. It is supplied complete or as a motor-pump assembly.

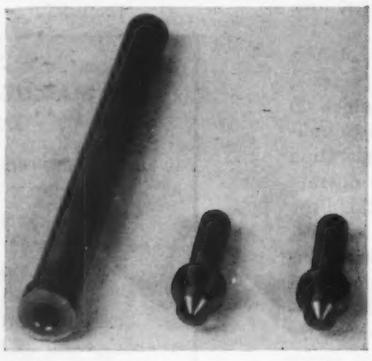
Durametallic Oil Pressure Unit

Valve

McKENNA METALS COMPANY

A new valve, designated a slow-up valve, with a ring of Kennametal inserted in the valve seat and cone-shaped piece of Kennametal ground and lapped to the same angle chamfer, has been announced by McKenna Metals Company, Latrobe, Pennsylvania.

Described as resistant to both erosive and corrosive action, they are designed for use in the oil industry where oil containing sand exerts severe wear on valves, in the gas industry where corrosive gases are encountered, in the chemical industry for use in acid-proof pumps and similar equipment, and in other industries where resistance to abrasion and corrosion is important.



McKenna Metals' Kennametal Valve

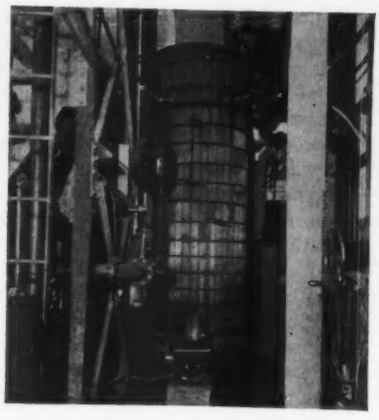
Kennametal, in grade KH, has a rated hardness of 78 Rockwell C or 91 Rockwell A, and is described as sufficiently strong to enable valves on which it is used to resist breakage.

Decarbonator

COCHRANE CORPORATION

A decarbonator designed to remove corrosive gases, including carbon dioxide and hydrogen sulphide from the water in cold condition without regard to other soluble gases, such as oxygen, has been announced by Cochrane Corporation, 17 Street & Allegheny Avenue, Philadelphia.

The decarbonator is designed to remove carbon dioxide from the effluent of carbonaceous hydrogen zeolite softeners and from water supplies treated with acid. Where soluble iron and carbon dioxide are present in the natural water supply, the decarbonator removes the dissolved carbon dioxide and by aeration oxidizes the soluble iron so that it may be filtered out and the water made fit for use.



Cochrane Corporation's Decarbonator

Constructed mainly of cypress or redwood, it is equipped with a rotary blower and fitted with corrosion resistant metals.

Gauge Covers

ASHCROFT GAUGE DIVISION

A new plastic gauge cover, designated Durafronts, has been announced by the Ashcroft Gauge Division of Manning, Maxwell & Moore, Inc., Bridgeport, Connecticut. It is designed to eliminate possibilities of workers being injured by broken or flying gauge glass.

The gauge fronts are molded of crystal-clear plastic with a tensile strength of 5000 pounds and a compression strength of 15,000 pounds. They are available in 3½-, 4½- and 6-inch sizes, and may be added to any plastic gauge now is service.

Gaskets

VICTOR MANUFACTURING & GASKET COMPANY

A gasket embodying in combination properties of asbestos and neoprene has been introduced by Victor Manufacturing & Gasket Company, Detroit. In manufacture, the gaskets are blanked from asbestos sheet material and then coated with neoprene cement devel-

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(Send for Bulletin No. 1300—Recording; No. 1500—Dial)

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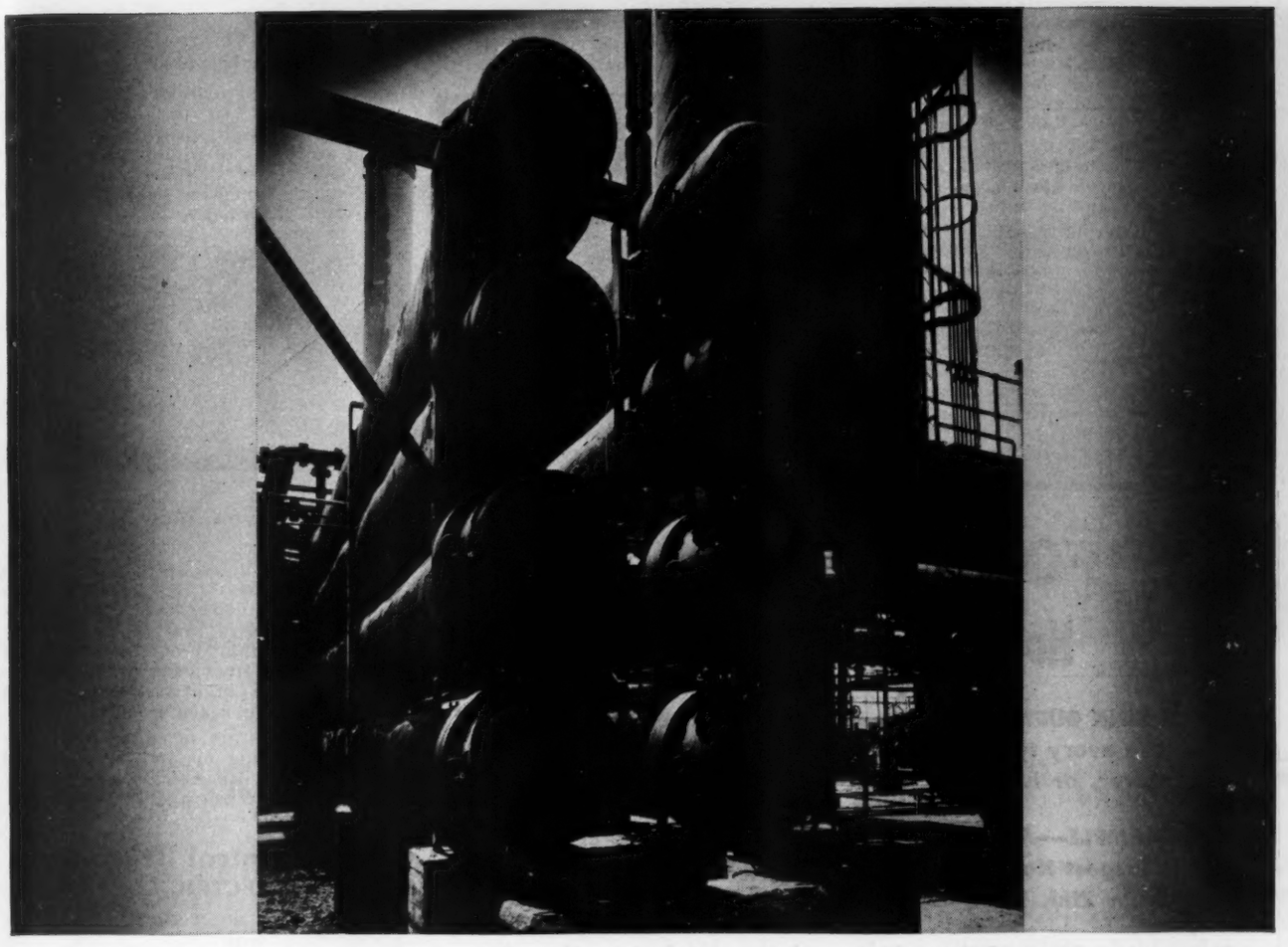


LIFE EXTENSION FOR HEAT EXCHANGERS

The choice of materials of which they are made, no less than the design, determines whether refinery heat exchangers will be a decided economic advantage or a source of expense and trouble.

The service makes very definite demands in the way of physical properties in the steel to be used. These demands are met admirably by Chromium-Molybdenum (4-6% Cr) steel.

This steel combines adequate strength at operating temperatures, absence of susceptibility to temper brittleness, and good resistance to corrosion. As a result the effective life of heat exchangers made of this steel is lengthened and the possibility of partial or total interruption to production is minimized.

Complete data on Chromium-Molybdenum and other heat-resisting Molybdenum steels for refinery use are contained in Section 8 of our technical book, "Molybdenum in Steel." Either the complete book or the individual section will be sent free on request to interested executives or engineers.

PRODUCERS OF MOLYBDENUM BRIQUETTES, FERRO-MOLYBDENUM, AND CALCIUM MOLYBDATE

Climax Molybdenum Company
500 Fifth Avenue, New York City

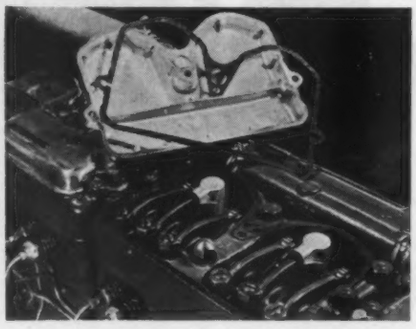
MOLY

oped especially to increase its resistance to passage of gases and liquids.

Two types are available. As originally made, the sheet has considerable compressibility, and gaskets made from it are adapted to joints where relatively light flange pressure is applied, as between light metal stampings. They are applied where heretofore treated paper, cork or similar materials have been used. They are designed for stability of dimensions and resistance to effects of relatively high temperatures that cause other materials to develop leaks.

A second type of gasket is obtained by compressing the asbestos-neoprene combination. They are designed for use where heavier flange pressures may be applied, as between machined surfaces.

In the presence of oils, motor fuels, and water, the gaskets are described as non-corrosive to steel, copper, brass, aluminum and magnesium alloys.

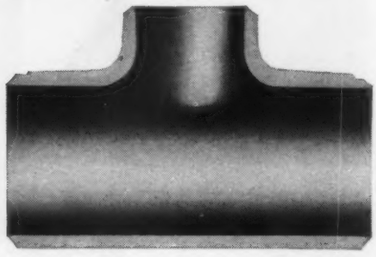


Asbestos-Neoprene Gasket on Valve Rocker Cover of a Diesel Engine.

Welding Tee

TUBE-TURNS, INC.

A new line of seamless steel welding tees, designed to provide full pipe strength through proper placing of metal at points of higher stress rather than by excess thickness throughout, has been designed by Tube-Turns, Inc., Louisville, Kentucky.



Tube-Turns' Welding Tee

The tee provides more metal thickness at the crotch and the thickness from that point, along the top centerline of the run of the tee, is gradually reduced to nominal at the bottom of the tee where stresses, when reinforcement at more highly stressed points is ample, again reach normal.

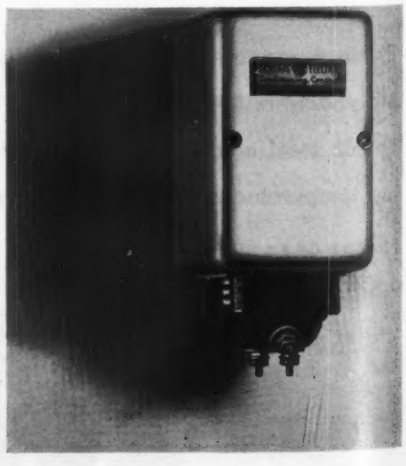
Long outlets are provided for greater ease in lining up and welding, and the tees are described as accurately machined, scale-free and stress-relieved.

Stoker Control Relay

GENERAL ELECTRIC COMPANY

A relay for controlling a stoker in conjunction with time switch, limit controls and room thermostat has been announced by General Electric Company, Schenectady, New York. It is designed also as a relay for blower motors of unit heaters controlled from room thermostat, as a relay between room thermostat and condensing unit in central plant-cooling systems, and as a relay between humidistat and humidification systems.

The device combines in one assembly a relay, low-voltage control transformer and terminal board. It is designed primarily for use with a hold-fire timer and limit control to form a complete stoker-control system and to provide a control link between any low-voltage



G.E. Stoker Control Relay

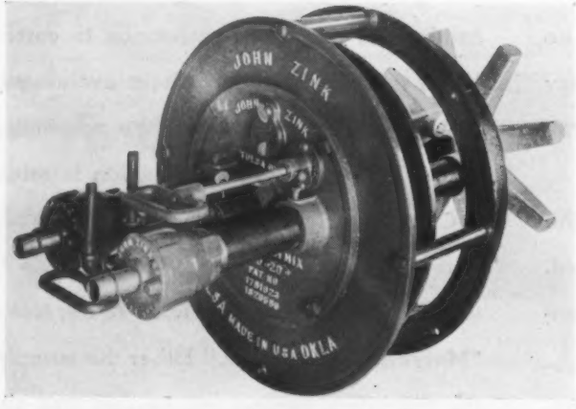
PERFORMANCE

No Other Burner Can Match!

JOHN ZINK BURNERS out-save, out-perform, and out-last all others in every type and capacity whether for drilling, cracking, power, or heating.

FOR EXAMPLE—A few months ago competitive burners in one of the largest Kellogg Units on the Gulf Coast were replaced with John Zink Dual Aspirator Bi-Mix Burners.

The performance of these burners is so satisfactory that the same company gave us a repeat order last month for the same size and type of burners to replace competitive burners in one of the largest Kellogg Furnaces in the Chicago area.

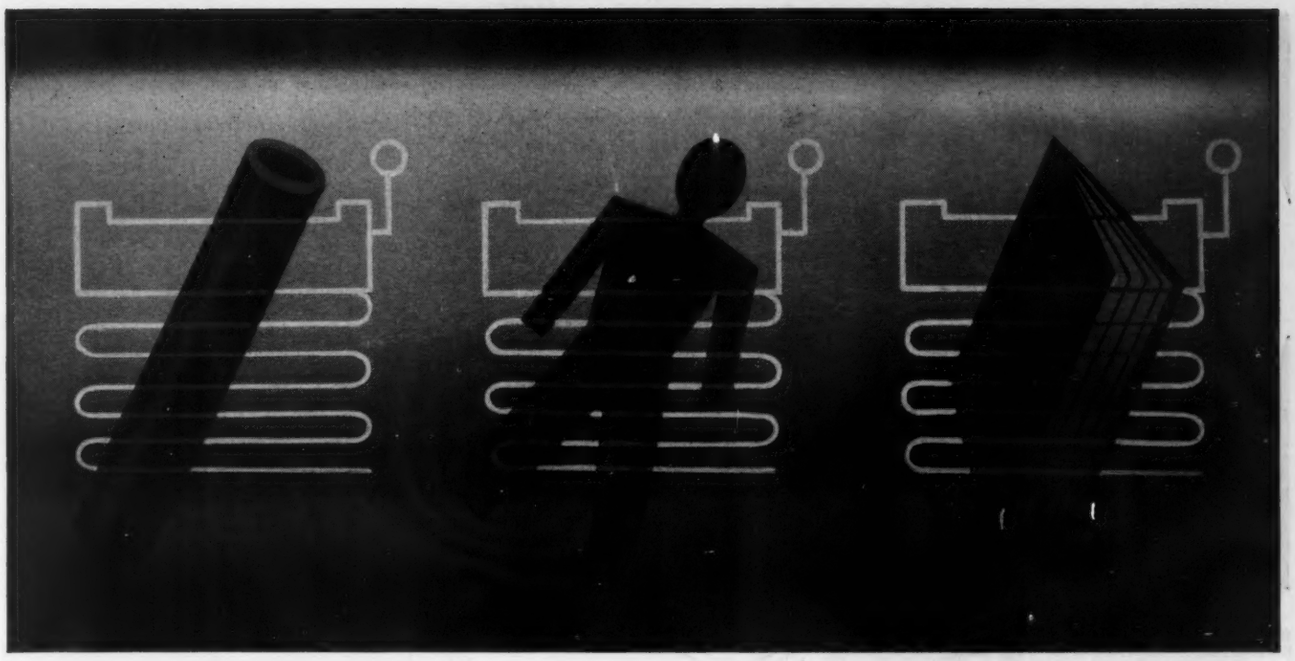


John Zink Dual Aspirator Bi-Mix Burner

JOHN ZINK COMPANY

Burners • Floor Furnaces • Unit Heaters

TULSA, OKLA. NEW YORK CITY



HERE'S A 3-WAY SERVICE TO LESSEN YOUR CONDENSER TUBE PROBLEMS

There are three major services you receive, at no extra cost, with every pound of condenser or heat exchanger tube you buy from Scovill. Here are the three aids you get, each contributing to trouble-free service:

SERVICE IN METALS — consisting, first, of laboratory development of new alloys fitted for better and longer service under particular operating conditions. For example, a Scovill Copper Nickel Alloy has been found to give more economical service under certain conditions of operation even though the per pound cost of the Copper Nickel is considerably higher than the Admiralty Metal previously used in many such cases. Then there's the constant vigilance of inspection of raw materials, and of finished tubes. You can expect uniformly high quality on every shipment from Scovill.

SERVICE IN MEN — Scovill's engineering representatives who also serve you in two ways. When they first contact you, they study the conditions under which you operate, and carefully prescribe the alloy that will serve you longest, with least trouble. Then, after the tubes are installed, they don't forget you—they maintain a field staff to check on how the tubes are operating in service. If anything is wrong, they go to work to find and root out the trouble. A case in point — a customer thought his troubles were due to use of the wrong alloy. Scovill engineering representatives helped him cure the troubles by merely using a different method of installation.

SERVICE IN MANUALS—new reservoirs of knowledge about condenser and heat exchanger tubes have accumulated since the earlier editions of Scovill's manuals were published. We have just published a new edition of the 68-page "Condenser Tube Booklet." It is free for the asking. Send today for your copy. Address 15 Mill Street, Waterbury, Connecticut.

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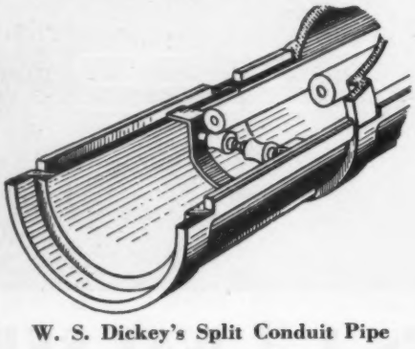
control instrument and power equipment. The transformer provides low voltage for use with a day-night clock or stoker timer.

Split Conduit Pipe

W. S. DICKEY CLAY MANUFACTURING COMPANY

A side-socket split conduit pipe for encasing underground steam or other lines requiring protection from alkali chemicals that cause disintegration has been announced by W. S. Dickey Clay Manufacturing Company, Kansas City.

The pipe, made in 4-, 6-, 8-, 10-, 12-, 15-, 18, 21- and 24-inch diameters, is vitrified and glazed, and has foundation burned in and the side socket sealed with asphalt to insure a tight joint.



W. S. Dickey's Split Conduit Pipe

The company has also announced an inproved 4- and 6-inch glazed clay acid-proof pipe for salt-water lines with a self-centering feature.

Braided Packing

THE GARLOCK PACKING COMPANY

A new braided packing, designated Lattice-Braid, designed to provide controlled porosity with every braiding strand passing diagonally through the body of the packing at an angle of approximately 45 degrees, has been announced by The Garlock Packing Company, Palmyra, New York.

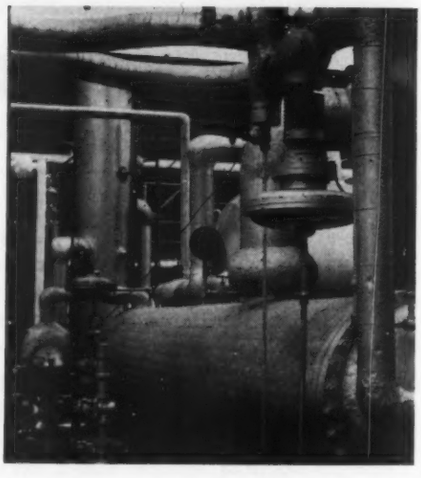
The packing is described as braided internally as well as externally, as having no strands in the packing that are not part of and integral with the entire body of the packing, and as presenting a structure in which every braided strand contributes to the strength of the entire mass.

Garlock Lattice-Braid Packing

Available in five styles, No. 730 is recommended for service on shafts of centrifugal and rotary pumps handling hot or cold water, caustic solutions or weak acids; No. 731 is recommended for service on rods operating against steam, gas, acids, lye and caustic soda solutions; No. 732 is recommended for heavy duty service against high pressure steam or hot oil; No. 736 is recommended for service on shafts of centrifugal or rotary pumps handling acids or strong chemical solutions, and No. 751 is recommended for application to shafts of centrifugal or rotary pumps handling cold oil or water.

HANLON-WATERS Type 97 RF Reboiler Controller

● The Answer to Stabilized Temperature Control Problems.



● Pressure compensation by the heating medium in the steam chest permits the regulator to anticipate and correct for changes of temperature before they are transmitted to the temperature recorder controller. Controlling this steam pressure, rather than the steam flow through the conventional motor valve, gives superior control.

NO STUFFING BOX—NO FRICTION
Eliminates necessity for Valve Positioner

Stability of pressure control reduces time required for changes of operating conditions . . . Applicable for service on any operation where a condensable heating medium is used.

Available in all pipe line sizes, ½-inch to 12 inch. Complete information and prices available at your nearest HANLON-WATERS representative.

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